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METALLOGENETIC EPOCHS.[1]

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The difficulties of a student of mineral deposits are increasing. As in petrography the first descriptive period of the science is drawing to a close. We know the principal types, and, though much remains to be done in detailed accounts, it seems that we are gradually coming to the same "impasse" which confronts the petrologist, who is now turning to the exact experiments of physical chemistry for the solution of the riddles which confront him. And as we transfer some of our most important problems into the same able hands for experimental work at high temperatures and pressures, some of us may confess to a slight feeling of disappointment that inductive work has failed to furnish definite answers to many of our questions. But such a state of mind should only be like the shadow of a passing cloud; for the study of mineral deposits is not a science distinct from others; it leans on all branches of geology as well as on chemistry and physics, and this new development means only that we have taken a step in advance; that we have acquired a new and powerful collaborator; it means also still further specialization. It does not mean that the scientific services of the mining geologist will be unnecessary or futile. His work will be necessary to assemble and assort the facts, to test the results of the laboratory,

[1] Read at the meeting of the Canadian Mining Institute at Montreal, March, 1909.

to propound new problems, and to generalize from the study of wide areas.

This critical examination of mineral deposits over wide areas is a work which now confronts us. It is the geographic and historical side of our science. With some hesitation I venture to place before this Institute an epitome of the principal epochs of the segregation of metals over our continent. Many of the facts are well known to you and the only feature of this paper which can possibly merit your attention is the summarizing of these facts.

This continent of North America is rich in metallic wealth; its total production exceeds that of any other equivalent division of the earth. Gold and silver come from the Cordilleran belt and also from the eastern margin of the continent. Copper in ever increasing quantities is derived from the Central Basin and from deposits in the west extending from Sonora to British Columbia. Lead and zinc are produced from our vast Mississippi basin and from the ranges of the Rocky Mountains. Half of the world's nickel is drawn from Ontario and a large part of the tungsten comes from Colorado. The total value of the metallic product of the continent in 1908 was about $1,000,000,000.

In some measure we have succeeded in classifying the vast number of deposits, not only with reference to their mineralogical and structural characteristics, but also with reference to their age. We find that metalliferous deposits have been formed since the earliest times of geological history. We find also that they are not equally distributed over the continent, but occur in metallogenetic provinces of greatly differing form and extent. Moreover, these metallic concentrations have not been going on at equal rates throughout geologic time, but the formation of each group corresponds to a fairly brief epoch which, with few exceptions, is also an epoch of vulcanism. No fact is better established than this, however much we may differ in details of genetic history. On the other hand, regions of vulcanism do not necessarily contain ore deposits. Naturally we find the ores in regions of uplift and erosion, for here the rocks are best exposed, but

they are not necessarily connected with such warpings and corrugations, as is illustrated by the oft-cited poverty in metalliferous deposits of the Appalachian ranges of sedimentary rocks.

Since the earliest times, then, metallogenetic epochs have recurred on the North American continent, and, comparing it with others, we must conclude that either the original sources from which the ores have been concentrated have been richer than elsewhere or the conditions for their formation have been more favorable than elsewhere.

In describing these epochs it will be convenient to separate the eastern and the western halves of the continent for, with exception of the earliest part of their history, they have little in common.

EPOCHS OF ORE DEPOSITION IN THE EASTERN PART OF THE CONTINENT.

1. *The Pre-Cambrian Period.*—The Pre-Cambrian period embraces a very long time and many differing epochs of ore formation; but for our present purposes it will be necessary to consider it as a whole. Ages of sedimentation alternated with violent igneous action. At many places long erosion preceded the deposition of the Cambrian. The Pre-Cambrian deposits form a belt along the southern Appalachians, extending northward into Canada, where they are found over a wide area. They occupy parts of Michigan, Wisconsin, and Minnesota, and reappear in the west, in South Dakota, Wyoming, Colorado, New Mexico and Arizona; possibly also in southwestern California, but with less of the diversity characterizing the Lake Superior region. In the latter region there is a great succession of igneous rocks, effusive as well as intrusive, ranging from granites to basalts, diabases and gabbros. In the Cordilleran region the intrusives are almost exclusively represented and the prevailing type is the normal red granite contrasting strangely with the later intermediate type of intrusives. Smaller amounts of intrusive diorite, gabbro and diabase are present.

The metals characteristic of this period are iron, copper, nickel,

gold and silver. Lead and zinc appear to be present in far smaller quantities than in later periods. Quicksilver and antimony are rare. The iron ores are, as well known, of several types; the ilmenites and the magnetites are chiefly of igneous origin; the hematites of Lake Superior, according to Leith, of partly igneous, partly sedimentary origin, and ultimately oxidized and concentrated by surface waters. It is believed that this concentration took place mainly in Pre-Cambrian time. The copper and nickel ores are connected with basic igneous rocks, in part intrusive, in part, as in the Michigan copper region, of effusive type. The concentration of the copper of this latter region into workable deposits also seems to have taken place chiefly, if not wholly, in Pre-Cambrian time, and probably followed the close of the igneous activity in Keweenawan time. The silver veins of Cobalt, which have proved so rich, are likewise Pre-Cambrian and some writers are inclined to connect them with Keweenawan basic intrusives into Huronian rocks.

In the Southern States the deposition of the gold-bearing quartz veins in most cases directly followed granitic intrusions in various sedimentary schists. The assertions of earlier writers, that these veins are genetically connected with basic intrusives, are not supported by recent work. Some silver and copper are associated with these gold-bearing veins. It should be added that some writers assign a Cambrian or even later age to the southern granites. Minor copper deposits in the same region are chiefly derived from intrusions of diabase or allied rocks. Pre-Cambrian gold-quartz veins are also known from Western Ontario.

2. *Epoch of Paleozoic Intrusives.*—From New York and New England northward into Quebec and Nova Scotia granitic intrusions took place at various times during the Paleozoic as late as the Carboniferous and were accompanied by some metallization. The gold-quartz veins of Quebec and Nova Scotia were in part, at least, formed after these intrusions, and various small deposits in New England have a similar origin.

3. *Epochs of the Sedimentary Iron Ores.*—Processes of sedi-

mentation under favorable conditions lead to concentration of iron ores. During the long period of unbroken Paleozoic sedimentation in the Appalachian region there were at least two epochs which are characterized by such iron ores. During the Clinton stage of the Silurian, persistent beds of low grade hematite were formed; and during the Carboniferous less important layers of carbonate black band ores were deposited.

4. *Epochs of the Triassic Traps.*—The important period of the history of the igneo-genetic ore deposits of the eastern part of the continent closed in the late Paleozoic and the majority of these deposits had been formed much earlier. A feeble recurrence of ore formation took place during the early Mesozoic, when the traps of the Eastern States were injected as sheets or overflowed as lava streams. Smaller masses of iron and copper ores developed along the igneous contacts, in part as veins, in part as contact metamorphic deposits.

5. *Cretaceous, Tertiary, or Later Epochs of Zinc and Lead Concentration.*—Since the Triassic, vulcanism has rested and in the eastern part of the continent metal deposits have formed only by the concentrating power of flowing surface waters or of groundwater in decaying rocks, or of ascending waters of atmospheric origin.

In the central valleys, such ore concentration has been effected in comparatively late time, apparently independent of vulcanism, and has resulted in the most important lead and zinc deposits on the continent. Regarding the mode of origin of these deposits opinions differ widely, but most observers believe that the lead and zinc has been leached by surface waters from Paleozoic limestones which derived their sparsely disseminated content from the pre-Cambrian northern continent. Some regard the process as a simple affair of downward percolating surface waters. Others attribute it to vigorous ascending circulation of atmospheric origin. The time of this concentration is thought to range from the establishment of a circulation dependent upon uplift, perhaps from the Cretaceous to the present time but some geologists have not hesitated to say that ore concentration began in late Paleozoic

or in Mesozoic time. Further discussion can not be attempted here, but with reference to the theories just indicated it may be worth while to point out that lead and zinc deposits are very scarce in pre-Cambrian rocks and the latter would hardly seem to be an adequate primary supply. There is undoubtedly much evidence in favor of concentration by ordinary surface waters, but the lead-zinc deposits in Kentucky and Arkansas certainly show transition into types, which closely resemble western types of veins, attributed to hot waters. The ores in the more important districts appear to convey the impression of sharply defined depositional epochs, rather than of long continued action of cold waters descending from the surface.

EPOCHS OF ORE DEPOSITION IN THE WESTERN PART OF THE CONTINENT.

The metallogenetic history of the Cordilleran region is more complex than that of the eastern half of the continent, but it is in some respects easier to interpret.

1. *The Pre-Cambrian Period.*—The Pre-Cambrian period, as already mentioned, was productive of gold and copper deposits scattered from South Dakota through Wyoming, Colorado, New Mexico and Arizona. South and west of this area the Pre-Cambrian is lacking; north of it, these old formations are present in places, but appear to contain no ore deposits formed during that period. In the Black Hills of South Dakota and in New Mexico some deposits referred to this group have been clearly shown to antedate the Paleozoic and others in Arizona give strong inferential evidence of as great geologic age.

The pre-Paleozoic gold deposits are generally lenticular quartz veins in schists, associated with heavy gangue minerals like tourmaline, garnet, etc. The copper deposits which usually contain chalcopyrite, are veins or irregular masses, the latter often of magmatic origin, but modified by dynamo metamorphism. Zinc blende is sometimes found with the chalcopyrite. Lead is almost wholly absent.

Throughout the Paleozoic and the larger part of the Mesozoic

the great interior province, now occupied by the Rocky Mountains, was the scene of almost uninterrupted sedimentation. Land areas existed here and there, but the igneous forces, so active over the whole country in pre-Cambrian time, were quiet for ages.

Not so along the Pacific coast; for here we find in places evidence of intrusions and lava flows dating back to the early Paleozoic. As yet it has not been shown that mineral deposits of that date exist along the coast except in the Copper River region in Alaska where copper ores are contained in greenstones of Carboniferous age; here as elsewhere it is probable that the metallization took place shortly after the eruption.

2. *The Early Mesozoic Epoch.*—Between the Carboniferous and the Triassic, uplifts and folds had raised the Paleozoic sediments and the early Mesozoic beds were deposited unconformably on the older rocks. Some time during the Triassic an epoch of intense igneous activity began and continued through the Jurassic. Basic lavas, mainly of the types of diabases and andesites, were erupted, largely as volcanic flows, from California to Alaska. A distinct epoch of metallization, principally yielding copper deposits, accompanied or followed these eruptions. We shall not err greatly in ascribing some copper deposits of California and British Columbia, to this, the second metallogenetic epoch definitely recognized on the Pacific coast.

3. *The Late Mesozoic Epoch.*—The third and most important epoch followed the intrusions of the great batholiths of the Pacific coast to which an early Cretaceous age is generally assigned. These intrusions of intermediate quartz-monzonitic or granodioritic character took place upon a scale difficult to grasp in its immensity. The present exposures show two main granitic masses, possibly connected beneath the Tertiary lavas. The southern batholith extends through California, the northern batholith stretches from Washington up through British Columbia to Alaska. Another smaller mass now occupies the central part of Idaho. Innumerable intrusives of less volume broke through the crust in Southern California, Southern Arizona,

Western Nevada, Oregon and elsewhere. The age of the batholith of Western Montana is somewhat in doubt, it may belong to a later epoch. But throughout this revolution and the birth of the mountain ranges on the coast, the Cretaceous was being quietly deposited at sea level all over the eastern Cordilleran region.

An epoch of intense metallization followed these intrusions, within the areas indicated. The great interior masses of the batholiths are usually free from deposits, as shown in the High Sierra, in the Clearwater region, and in British Columbia. But along their margins mineral deposits formed in abundance, as along the gold belt of California, and along the two contacts of the batholith of the Canadian and Alaskan coast regions. The latest researches by the Alaskan division of the United States Geological Survey indicate that the great placer fields of Alaska derived their gold from deposits of this epoch. Gold, primarily, and copper, secondarily, are the characteristic metals. Along the Pacific coast, where there is little limestone in the intruded sediments, lead is practically absent, but in the interior, as in Nevada and Idaho, where the intrusions came into contact with Paleozoic limestone, this metal, with zinc, begins to appear. Silver is everywhere present, but scarcely ever important, except where lead appears. Arsenic and antimony are not abundant, mercury is nowhere present in commercial quantities.

4. *The Early Tertiary Epoch.*—As if exhausted, the igneous forces appear to have rested until the close of the Cretaceous and then broke out in a new field, along the eastern margin of the Cordilleran region, at that time largely covered by a plastic mantle of Cretaceous shales and sandstones, several thousand feet in thickness, which rested on great accumulations of Paleozoic limestones.

The predominating magmas were again of intermediate character, and solidified as granular or porphyritic rocks, standing between the granites and the diorites; they contrast markedly with the potassic and acidic magmas of pre-Cambrian times. While it is not necessary to limit strictly this igneous activity

to a certain time, there is little doubt that most of it took place in the Eocene. The eruptions mainly took the form of intrusions and largely that of laccoliths, undoubtedly because, unlike the conditions of the shattered rocks of the Pacific coast, they were covered by this heavy, tough and still yielding mass of Cretaceous sediments. We find an enormous number of these intrusions as sheets or laccoliths at various horizons between the Cambrian and the Cretaceous or as dikes or stocks that break through the underlying pre-Cambrian. They are rarely comparable in extent to the great batholiths of the coast. They occur from British Columbia, through Montana, Colorado, New Mexico, eastern Arizona, and probably attain their greatest development in eastern Mexico. For reasons already indicated many, perhaps most, of these intrusives never reached the surface. Only in a few cases, as in Montana and in Colorado, near Denver, do the strata of Laramie or Eocene age contain volcanic detritus.

The third Cordilleran epoch of metallization followed these intrusions; contact metamorphic deposits and veins were formed in abundance around their margins. The characteristic metals are silver and gold with much lead and zinc, especially where the intrusions cut the limestones. Copper and iron are also present at such limestone contacts. Arsenic and antimony are far more in evidence than during the second epoch, but mercury is still absent.

5. *The Late Tertiary Epoch.*—Orogenic disturbances followed the intrusions; the whole Cordilleran region was lifted high above sea level, warped, and faulted. These disturbances may have facilitated sub-aërial eruptions; at any rate it is certain that the middle and close of the Tertiary witnessed outflows of lavas upon a magnificent scale.

These eruptions spread over large areas of the western part of the continent; less pronounced in British Columbia and Alaska, they are abundantly represented in California, Washington, Oregon, Idaho, Colorado, Utah, Nevada, New Mexico, Arizona, and attained their greatest development in Mexico. Andesites and rhyolites are the predominating rocks. In some places the flows attained such thickness that during the later part of the

volcanic epoch intrusions of magmas consolidated in them with granular structure.

During these eruptions, not strictly contemporaneous throughout, a fifth metallization took place, of which the characteristic metals are gold and silver. These deposits were often of great richness which is further accentuated by secondary processes; in fact most of the "bonanzas" belong to this class. Lead and zinc are not conspicuous except where the metallization took place in limestone. Copper is not abundant. Tellurium and antimony are common. Not that they are absent in older metallizations, but they, especially tellurium, seem particularly characteristic of this epoch.

Large areas of volcanic rocks are barren. The metal deposits seem to have formed only near or at the foci of igneous activity, where connection could be established with underlying magmas. The most recent eruptions were mainly basalts, and these, except in one case, do not seem to have been affected by metallization.

6. *The Post-Pliocene Epoch.*—The youngest metallogenetic province is that of the Pacific coast line. It is of very late age—Post-Pliocene apparently, and is characterized by mercury accompanied by few other metals. It developed in the Coast Ranges of California, following basalt eruptions and contemporaneous with it was a great development of hot springs. In part the deposition goes on at the present time.

Note that the quicksilver did not develop simultaneously with the birth of the Coast Ranges; these are much older, and an active circulation of atmospheric water was undoubtedly established long before the quicksilver deposits were formed.

7. *Cretaceous or Later Epochs of Copper Concentration in Sedimentary Rocks.*—In addition to these six classes, whose connections with igneous rocks are indubitable, the disseminated copper ores of the south-west should find mention. They occur in sandstones, shales, or conglomerates ranging from the Carboniferous to the Cretaceous, and, in most cases, chalcocite is the primary ore; frequently small amounts of silver are present. New Mexico, Arizona, Utah, Colorado and Texas offer numer-

ous examples of this class. While their origin is not wholly clear, many observers believe that they represent concentration by groundwaters of small amounts of copper originally derived from the pre-Cambrian deposits and since distributed through late sedimentary beds.

Summing up we have then in the Cordilleran region:

	Principal metals.	Principal rocks associated with deposits.
1. Deposits of the Pre-Cambrian period:	Gold and copper.	Granites. Diorites, gabbro.
2. Deposits of the early Mesozoic epoch:	Copper.	Basalt, diabase. Gabbro.
3. Deposits of the late Mesozoic epoch:	Gold.	Granodiorite. Quartz-monzonite.
4. Deposits of the early Tertiary epoch:	Gold, silver, copper, lead, zinc.	Granodiorite. Quartz-monzonite. Monzonite, with corresponding porphyritic rocks.
5. Deposits of the late Tertiary epoch:	Gold, silver.	Andesite. Rhyolite.
6. Deposits of the Post-Pliocene epoch:	Quicksilver.	Basalt.
7. Cretaceous or later concentrations in sedimentary rocks.	Copper.	Sandstone, shale, Conglomerate.

In deposits that are clearly connected with igneous rocks metallization is certainly a function of varying pressure and temperature; these factors being dependent upon depths below the surface and other conditions; metallization is also dependent on the nature of the rocks in which deposition takes place. Primarily, however, it is probably a consequence of magmatic differentiation.

It is well established that magmas of different types contain different associations of the rare metals. For instance, tin and tungsten characterize acidic rocks, while nickel and cobalt are found chiefly in magmas rich in ferro-magnesian constituents. At the same time rocks of a given general composition may, in different localities, vary considerably in the quantity of rarer metals contained.

Our knowledge of the content of rarer metals in igneous rocks is fragmentary, but it is at least often the case that ore deposits formed after the eruption of an igneous rock will contain the rarer metals characteristic of it. It may be true that for each differentiated rock type there are corresponding types of deposits, varying with the conditions of deposition.

As periods of long continued differentiation may materially modify the composition of a magma, it is conceivable that this might find expression in a progressive change in the character of ore deposits successively formed during these periods. The quicksilver deposits of California, for instance, may be the ultimate result of such long continued differentiation.

Perhaps it may be thought that the limits of epochs of metallization have been drawn too closely in this paper. It is freely admitted that in many cases there may be room for doubt. But if this opening of the question will stimulate discussion of this vital subject it will have achieved its most desired result.

SOME PHENOMENA OF THE FOLDING OF ROCK STRATA.

FRANK L. NASON.

I.

For several years past, while travelling professionally in the Rocky Mountain area in the United States and Mexico, I have been profoundly impressed by the acute crenulation of mountain ranges which spring from the elevated plateaus of the Rockies. I use the term " crenulation " advisedly. Folding into anticlines and synclines is a term altogether too mild to suit the facts. The sudden and acute changes of dip and strike, changes from 0° to 90° or more in dip (in the case of " more " an overthrow fold is implied) seem, at first sight, to call for profound earth movements with corresponding faults and fissures of commensurate depth.

In considering this plausible explanation one is immediately confronted with a paradoxical if not a contradictory negative phenomenon. In profound rupturing or faulting, one would naturally expect eruptives in the form of bosses, intrusives and dikes, either one or all; while the contrary is in many cases true, all forms of eruptives are strikingly conspicuous by their absence.

The interpretation of the above has a decided economic value, but more than this, even, the calculation of the depth of a given fissure often becomes of prime importance from the standpoint of the miner.

Mineral deposits of all kinds are found in fissures (so-called veins) in blankets or their Mexican equivalents, " Mantos," in lenses and " shoots," " chimneys " and " blowouts." These terms have no exact and distinctive meaning but depend, for their application, wholly upon the interpretation of the individual. The reason for this confusion is not far to seek. It appears to me that pains have not been taken to reason out carefully the basic facts of these phenomena.

To the miner a "fissure" is always hopeful. A fissure suggests profound depth; if mineralized at the outcrop, "inexhaustible" immediately comes to his lips. Yet "fissures" "pinch out" and disappoint. A promising "fissure vein" develops only a "pocket" in which not only the mineral but the vein or fissure itself "pinches out"—wholly disappears.

I am sure that more or less directly this question has suggested itself many times to the thoughtful economic geologist—"Is there a real fundamental reason for this or is it an inexplicable 'freak of nature'?"

Other questions of a similar nature may or may not have been suggested. We know these to be facts. Many fissures, mineralized at the outcrop, have been worked to several thousand feet in depth with no diminution of values. Other fissures have developed only "pockets," and extensive and costly exploration has failed to find other pockets; even the fissure itself has disappeared. Still others, hopeful, though barren at the outcrop, have continued to be barren even in depth, and this too when another, and not distant fissure, cutting the same rock outcrop, is a heavy producer to a great depth.

In other instances a great blanket or manto leads towards a fissure or fault, but before reaching the fault the ore either wholly disappears or fades into a mere "stringer" and at the fault and in the fault wholly disappears.

Are there data accompanying these phenomena which, when grasped and mastered, will aid in distinguishing a comparatively shallow from a profound fissure, which will aid the geologist or engineer in forming, within reasonable limits, an opinion as to the maximum or minimum depth of a given fissure?

I advisedly omit from this proposition the question of economic mineralization, since, so far as we now know, mineralization, in the economic sense of the word, is an inexplicable accident, not a tangible, sure deduction. If mineralization is predicted it must yet rise to no higher rank than a guess; unless put forward on probabilities based on a wide and intelligent experience.

In the Rocky Mountains and their extension into Mexico.

mines are predominatingly found in undoubted sedimentaries from the Cretaceous down. These sedimentaries are in many places evidently thousands of feet thick. Contrary to the general opinion of selective deposition, *i. e.,* mineral deposits occurring in some one or two particular strata, wide experience seems to teach the careful observer that the contrary is true and that any one of a series of limestone rocks thousands of feet thick may be and often is mineralized.

One is thus forced to the conclusion that selective deposition, generally based on the idea of some favorable chemical composition of the limestones (though undoubtedly a factor), usually ascribed to carbon, is, in many cases at least, a misleading if not a wholly mistaken idea.

II.

In considering the acute crenulation of sedimentary rocks, I shall draw, for the purposes of illustration, from the range of mountains known as the Sierra Madre Oriental, running southwesterly from Monterey, Nuevo Leon, Mexico.

At Santa Engracia, a station on the Mexican Central Railroad, in Tamaulipas, the elevation is 400 to 500 feet. Seventeen miles west, at the foot of the Sierras, the elevation is probably 600 to 800 feet, while four miles in the mountains, and in the bed of a river, the elevation, by barometer, is 1,200 feet.

It is at this point that the geological section, Fig. 69, begins. Going west the trail leads up over a mountain with a barometric elevation of 7,000 feet. The trail starts on formation *F* and up to 6,000 feet the trail leads over nearly horizontally bedded sandstones and shales. The next 1,000 feet is as shown in the section.

It is probable that formations *C, D, E* and *F* are Upper Jurassic since fossils which I submitted to Dr. Charles Schuchert from formation *C* were identified as belonging to the Upper Jurassic.

Formation *B* is not barometrically determined since for the most part it is the crest of a mountain, but I estimated the thickness from the upturned or tilted rock strata.

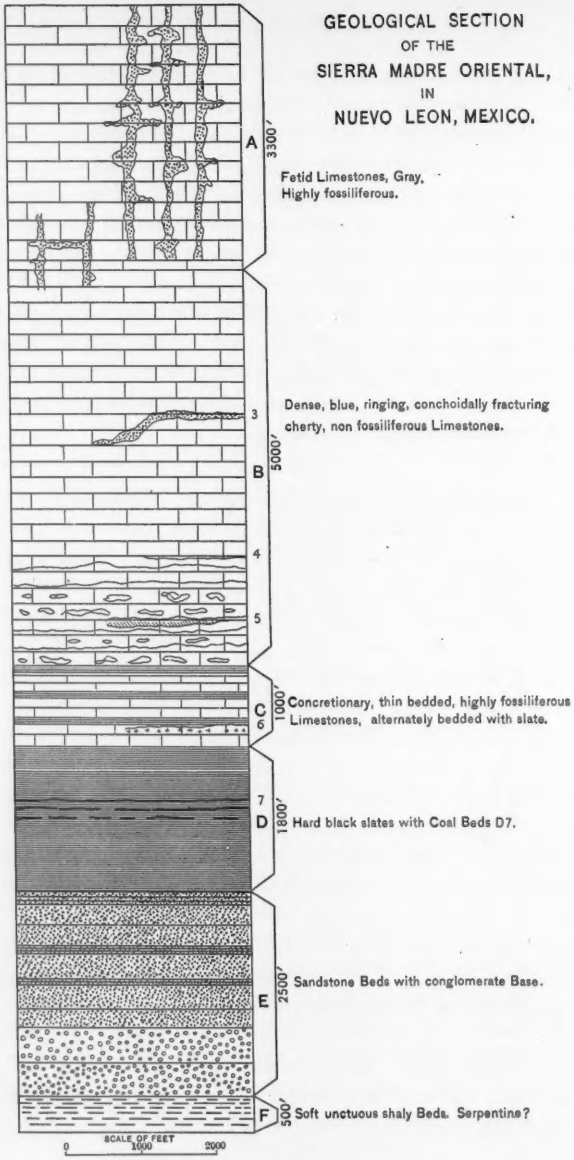

GEOLOGICAL SECTION
OF THE
SIERRA MADRE ORIENTAL,
IN
NUEVO LEON, MEXICO.
A
3300′
Fetid Limestones, Gray.
Highly fossiliferous.
3
B
5000′
Dense, blue, ringing, conchoidally fracturing
cherty, non fossiliferous Limestones.
4
5
C
6
1000′
Concretionary, thin bedded, highly fossiliferous
Limestones, alternately bedded with slate.
7
D
1800′
Hard black slates with Coal Beds D7.
E
2500′
Sandstone Beds with conglomerate Base.
F
500′
Soft unctuous shaly Beds. Serpentine?
SCALE OF FEET
0
1000
2000

FIG. 69.

A is more accurately determined since in a distance of five miles we rose from 4,000 to 7,100 feet. This gives a probable vertical thickness

	Feet
To the Upper Jurassic *C, D, E, F,* of.....	5,800
To the Cretaceous, *A–B*.....	8,300
Or a total thickness of exposed rocks of.....	14,100

Northeast from the eastern foot of the Sierras, a great rolling plain reaches across the state of Tamaulipas to the Gulf of Mexico. The elevation at the foot of the mountains, as stated, is 800 feet. The Sierras proper, extend about 40 miles due west. While the maximum elevation given on the official map of Neuvo Leon is 2,612 meters, I judge that many peaks will reach over 3,000 meters. West of the western slope of the Sierras is the great Central Plateau of Mexico with a general elevation of over 5,000 feet.

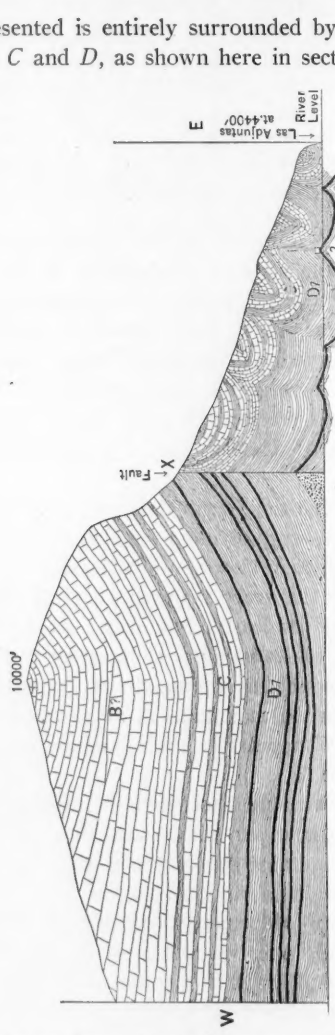
It will thus be seen that the Sierra Madre Oriental Mountains, as a whole, form a great scarp dividing the plateau from the Gulf Plains; that the difference in elevation is at least 4,200 feet. It is more than likely that this scarp represents a great fault with a vertical displacement of at least 4,200 feet. It is reasonably certain that the plains of Tamaulipas at least for a distance of two miles east of the mountains are mainly of formation *C,* that formation *F* appears in the mountains at an elevation of 1,200 feet, while formation *C* appears in the mountains at this place at an elevation of 7,000 feet.

The above, coupled with the facts that the average grade of drainage streams is about 2 per cent. or 106 feet per mile, and that in many places mountains rise within three to five miles of a given stream to a height of 7,000 to 10,000 feet, will make it apparent that in a semi-arid country exceptional facilities for for studying rock folding phenomena are present.

The geological section, Fig. 70, horizontal scale approximately 1 inch = 1 mile, gives a fairly accurate representation of rock folding from fault line *X* to Las Adjuntas.

Although not shown in the section, the 10,000 foot mountain

here represented is entirely surrounded by crenulated strata of formation *C* and *D*, as shown here in section. This mountain



EAST AND WEST SECTION
ON
RIO SAN BARTOLO
NUEVO LEON, MEX.

Fig. 70. Scale 1 inch = approximately 3 miles.

mass covers an approximate base area of 96 square miles, with slightly dipping basal rocks. A constant succession of lofty

limestone islands, surrounded by troubled slates is presented in this range.

From a study of these actual rock formations the ideal section, Fig. 71, was evolved.

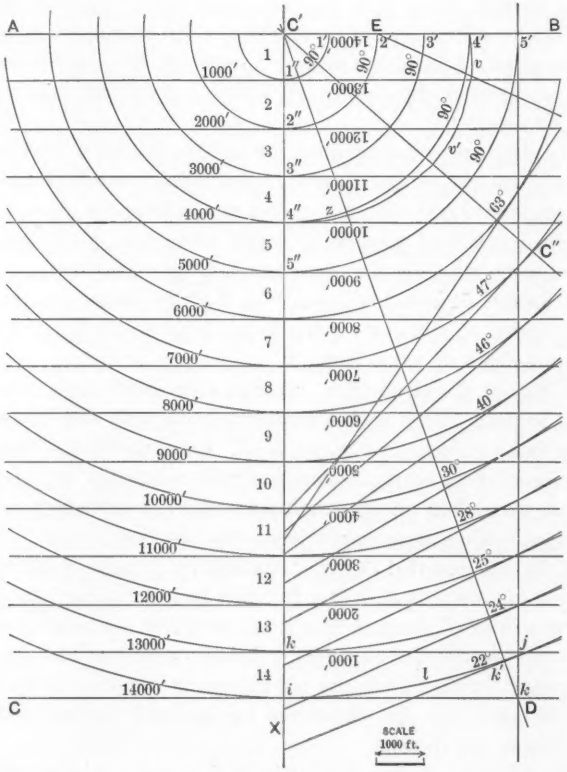


FIG. 71. Ideal section of rock strata of section in Fig. 70 showing upward increase in curvature.

In this section I have assumed the thickness of rock strata to be 14,000 feet as indicated in Fig. 69. Considered as a synclinal fold the section is begun on base line *C–D*, and in formation *F*.

If now stratum *14* be folded on one leg of the syncline at an angle of 22°, it will be seen that tangents to the concentric curves will, at 1,000 feet intervals, increase from 22° to 24°, 25°, 28°, etc., to stratum *5* where the tangent to the curve represents a dip of 90°.

Without allowance for rock compression it will be seen that starting with a basal initial dip of only 22° the superincumbent stratum at 9,000 feet will have a dip of 90°, with a base, *i–k*, of 5,280 feet.

The depth to which an angle of 90° would reach depends, of course, upon the surface contour. Assuming a nearly flat-topped mountain of 4,000 feet, arc 1 foot would keep its dip approximately, for at least 500 feet in depth; arc 2 feet, 1,500 feet; arc 3 feet, even allowing for slope line *EF*, for 2,000 feet.

If instead of a steady grade line, *EF*, the slope descended in a succession of cliffs, arc 4 feet would hold an angle of close to 90° to a depth of 3,000 feet.

In Fig. 71 the assumption has been a perfectly concentric synclinal trough. That such a structure is not only *not* impossible but actually occurs, see Fig. 70, *X–E*. Here within a distance of three miles three nearly concentric synclines actually occur. This section was taken on the south side of an east-flowing stream. The north side was an approximate reproduction.

While it is true that in Fig. 71 strata *A–C'* might be horizontal or even dip towards *A*, it is a fact that in rock folding the structure as exhibited along *A–B* often occurs, that is a nearly perfect concentric series of rock strata. It is very evident also that the reverse or anticline structure is of frequent occurrence; by turning the plate top side down the surface and successive depth phenomena are shown.

The main point thus far established is this: *In a given rock series, a slight elevation of the basal members will produce continuously increasing displacement of each of the superincumbent rock strata.* There can be no question about this point. In many of the younger rocks of the mountain ranges of the plateau of the Rocky Mountains in the United States and espe-

cially in the Sierra Madre Oriental Mountains of Nuevo Leon in Mexico, changes in dip as shown in Fig. 71 can actually be traced.

With this point established several corollaries follow which are not at once evident.

Without going into primal causes of rock movement we may at once assume the fact. These rock movements resolve themselves into lateral thrusts, these tending towards the formation of anticlines and synclines of mountain dimensions. While the axes of these folds, as a whole, are remarkably constant in direction, sections of this axis may lie at any angle to the main axis. In order to have such an axis a uniformly straight line, two fundamentals would have to obtain, one of which, at least, is conspicuously inconstant. The first fundamental would be the assumption of thrusts and resistance of equal intensity along the entire axis of folding; the second fundamental would be the assumption of the uniform resistance of not only successive rock strata in depth but homogeneity of any given rock stratum along the whole axis. Such an ideal set of conditions is unthinkable. Therefore with variable intensity of thrust and eminently variable resistance to thrust, the resultant lines would constantly vary in direction. A given line of yielding cannot, as is often the case, be considered as a primal line of weakness or of least resistance, but the locus is determined by the resultant direction of energy and hardly at all by the resistance of rock strata to a crumpling force.

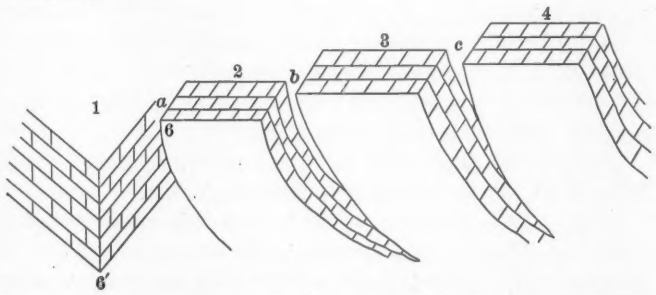


FIG. 72. Ideal diagram illustrating fractures resulting from unequal intensity of thrust and unequal resistance to thrust.

Assuming, then, a thrust of varying intensity and rocks of varying resistance to thrust, cross fracturing, fissuring, and faulting would be a few of the records of such variables.

If now Fig. 72 is consulted, it is evident that a block of horizontal rock, 1, and tilted blocks 2, 3 and 4 with dividing fissures *a*, *b* and *c* might and probably would be records of such variables. The interesting question would immediately suggest itself: *a*, *b* and *c* being either faults or "fissures," perhaps both, to what depth would they penetrate?

Except in the most general way I do not recall ever having heard such a question; certainly have I never heard a suggestion of the possibility of deciding the depth to which such a disturbance would reach.

In considering a possible answer to such a question I again refer to Fig. 71. In the flexing of stratum 14 to an angle of 22°, point *j* would rise from point *k* through a vertical distance of 1,000 feet. In this stratum the resulting curve *idj* would be so easy that a rupture strain would hardly occur. In stratum 1, however, the arc 1′–1″ would practically be bent at right angles in a radius of 1,000 feet; 2′–2″, 3′–3″, 4′–4″, 5′–5″ would have radii of 2,000, 3,000, 4,000 and 5,000 feet, respectively. The maximum shear would of course follow the axis of maximum movement. The shear would evidently be greatest where the arcs cut radius *C′–B* and would practically be zero on the radius *C′X*. For the purpose in hand therefore, fissures *a*, *b* and *c*, Fig. 72, referred to 1′, 2′, 3′, etc., Fig. 71, would extend in depth to radius *c′–C″*, 500 feet, 1,400 feet, 2,000 feet, etc., up to 5′ where depth of a fissure would be 3,400 feet. From radius *c′–c″* to radius *C′–X* rupturing strains would rapidly decrease in intensity to zero at the dead radius *C′–X*.

It thus follows that in the case cited in Fig. 71, the maximum depth of a large fissure would be about 3,400 feet.

In the unequal strains set up in mountain making, before briefly mentioned, sudden changes in dip from 0° to 90° can be accounted for. As an instance, refer to Fig. 72, 1 and 2. Here block 1 remains horizontal while along the break *a*, stratum 6,

standing at 90°, has been moved from *6'* to its present position. A fault or throw of feet proportioned directly to the thickness of the strata involved would die out wholly at the dead axis *C'–X*, Fig. 71.

Without going into farther detail, these conclusions seem to be warranted:

First: In any given locality the probable length and depth of any fissure can be predicted within fairly accurate limits.

Second: In any given locality the distinction between a purely limited break and profound orographic "true fissure vein" can be readily reached.

It thus occurs to me that a new and powerful weapon is available for the mining geologist with which to attack his problems.

What should, perhaps be added is the following: A fissure such as *a, b* or *c*, Fig. 72, may come into existence under a set of conditions favorable to mineralization. The fissure might thus be a "mineral vein." This fissure, whatever its economic value, would become a drainage channel. With the lowering of base level drainage to the right of *C''*, Fig. 71, the radius *C'–C''* would be lowered. That is, the fissure would be deepened. This deepening would continue indefinitely while mineral circulation and deposition would have ceased at *C'–C''*. It would thus happen that a rich mineral fissure *C'–C''–B*, would, for the above reasons, be wholly barren below *C'–C''*.

III.

There remains to be considered another factor of equal importance and wholly inseparable from the first. In nearly all disturbed areas there are more or less evidences of heat action. The evidences of this agent are regional and contact metamorphism, fumaroles, mineral veins. The casual observer even has frequently noticed, in mineral regions, that one limited area is mineralized while the remainder is wholly barren; that a thin unattractive vein outcropping in wholly, or at most, only partially metamorphosed rock, if followed in leads to a large blanket or manto; that in following a blanket or manto towards a fissure

or crushed zone, not only does the mineral wholly disappear but the thick metamorphosed blanket even, nearly or quite disappears as well. Correlated facts are also frequently observed; viz., if the fissure is mineralized the mineral leads from the manto into the fissure, while, if the fissure is barren, the reverse is often true. There are notable, if not frequent instances where a rich blanket has been accidently discovered which has given little or no direct surface indication of its existence.

In the passing of judgment on new or unexplored ground, or the probable extension of known ground are there any tangible data observable which will guide either to a favorable or to an unfavorable conclusion as to probable mineralization?

In attempting to answer such a question one must always keep in mind the *stability* of any given mineral. Gold, platinum, magnetite iron ores, etc., rarely or never migrate from their point of origin, except as "placers" derived by mechanical abrasion; while zinc, lead, copper and some iron minerals are readily migratory, moving from point to point, dissolving and reprecipitating, in response to favorable conditions.

The former class of minerals, *in situ,* are always accompanied by *heat* phenomena, except as placers; the second class may or may not exhibit such phenomena. In the second class, mineral *in situ* would almost certainly exhibit heat phenomena, while the absence of heat phenomena would almost certainly indicate that it had migrated by at least one remove from its point of primal deposition.

We are apt to ascribe heat phenomena almost if not quite exclusively to two causes:

1. To circulating gases or waters in fissures with depths profound enough to reach the supposed high temperatures of the inner earth shells; or,

2. To heat brought from equal or greater depths through the agency of eruptive rocks in the form of dikes, laccoliths, bosses, etc. Therefore, it is often more or less inexplicable when mineral phenomena are exhibited with heat concomitants with the entire absence of either profound faulting or of eruptive rocks.

What, then, is the source of this heat? I refer again to Fig. 71. Let us consider the block of ground *c'–i–k–5'*. This block is 5,280 feet × 1,400 feet × 1 foot. The weight per cubic foot we will assume to be 180 pounds. In a curve of 22°, point *j* has moved from point *k* through a vertical distance of 1,000 feet, while point *i* has remained stationary. The mean vertical elevation of the entire mass has thus been 500 feet. In this elevation, work has been performed equivalent to 6,652,800,000,000 foot pounds. Converting this into joules equivalent, 8,617,616,580 pounds of water will be raised 1° in temperature. Assuming the water to be at 32° F., to reach the point of evaporation this temperature must be increased by 180°. Dividing 8,617,616,590 by 180, the energy developed will evaporate 47,875,647 pounds of water. In a locomotive boiler one pound of coal will evaporate 6.5 pounds of water. But this water evaporated in a locomotive boiler represents only about 90 per cent. of the actual heat units of a pound of coal. The ratio of coal consumption to water evaporated is, however, actually established. Therefore the evaporation by 47,875,647 pounds of water in a locomotive boiler will require the combustion of 3,683 tons of coal.

Assuming that this energy is consumed in flexing this stratum into the arc *i–d–j*, additional energy will be required for the following work:

The stratum *14* laid originally in the position *i–k* and was 5,280 feet long. In assuming the position *i–d–j*, arc *i–d–j* is 324 feet shorter than the line *i–k*. Therefore *k'* will represent a horizintal slip of 324 feet. This corresponds to the movement of the block of ground *c'–i'–D–B* through a horizontal distance of 324 feet. This work will equal the combustion of about 3,000 additional tons of coal.

Going now to stratum no. 2, this would appear to have been moved the equivalent to a horizontal distance of 2,139 feet, equivalent to a coal consumption of about 1,841 tons. The mean coal consumption of slipping (strata *14* and *2*) will be about 2,762 tons; multiplying this by 12 and adding 3,683 tons for the

movement of the original mass, there is a total coal equivalent of 36,827 tons or 73,654,000 pounds.

If now, one pound of coal will raise 6.5 pounds of water to 212° F., and assuming that it would raise an equal number of pounds of rock to the same temperature, 478,751,000 pounds of rock will be raised to 212° F. The entire block *c'–i'–D–B* weighs 1,320,560,000 pounds. Therefore, assuming an original temperature of 32° F., the energy is equivalent to a mass temperature of 100° F.

It is not probable, however, that the slipping will be evenly distributed over each stratum, but will be confined to one or more planes. Therefore the total heat units developed will also be thus confined.

If this reasoning be correct, then the temperature developed in such restricted zones will certainly be very many times that of boiling water.

In this connection the time element is by no means to be ignored, remembering, however, that the total heat developed by friction will be the same in a thousand years or more or in less than one minute. The only requisite is that radiation or other means of heat dissipation must be less than the heat generated, whatever the time period. It is hardly necessary to call attention to the fact that under many conditions the heat conductivity of rocks may be regarded as practically nil. Even the duration of the time period may be closely approximated.

It is a well-known fact that rocks are not perfectly rigid bodies. Under slow heavy pressure the individual molecules will flow and the rocks may be acutely flexed without rupture. When such pressure is sufficiently applied, rupture can be almost certainly predicted as a clean, smooth, slickensided plane. A sudden application of a force of equal intensity would with equal certainty be predicted as a zone of crushed rock, there being no time for molecular readjustment.

In both of the above instances slipping of one plane over another would almost certainly take place, but in the latter case the time period of heat development would be reduced to a small

unit. Whether the heat generated in either case would be dissipated or would perform work, would depend upon other elements.

These elements are:

1. An open fissure or a zone of more or less coarsely ground rock.

2. A greatly disturbed area where large rock areas were broken into irregular blocks.

3. Where areas of ground, .5 to 3 or more miles square were left in a horizontal position or slightly bent or tilted, as *1* in Fig. 72, or even *2*, *3* and *4*.

First case, open fissures or zones of crushed rock. In either of the above, the open fissure or the crushed zone, the open spaces would supply channels through which either air or water would circulate freely. This would, of course, result in the dissipation of heat before it had an opportunity to perform work. Consequently, metamorphism would be impossible.

Second case, greatly disturbed area where rocks were crushed into irregular blocks. In this case, area is supposed to be shattered by numerous fissures, cutting the area into square or oblong blocks with more or less acute tilting. Here, whatever the heat generated by fracturing or slipping, numerous open channels would allow either air or water to circulate freely on all sides of a given block. However great the heat developed in a given block the relatively great area exposed would rapidly dissipate any amount of generated heat. Without starting a general law a few cited examples will give an idea of how great importance is the element of comminution in heat dissipation. Assuming equal initial temperatures in a cube of 1 foot and a cube of 10 feet the ratio of heat volume would be 1 to 1,000; 1-foot to 100-foot cubes would be 1 to 1,000,000. As the surfaces of each cube would be radiators the conducting line of the 1-foot cube would be .5 foot, of the 10-foot cube would be 5 feet, or ten times as great. Citing no further, it will be seen that, with the slow heat conductivity of rock masses, the cube of 1 foot would be cooled rapidly while the inner volume of a ten-foot cube might take months or even years.

The third case, rock masses with a base of .5 to 3 or more miles square, follows almost as a corollary from the second case, the difference being the degree of comminution. Only in this case the cooling of the interior mass of a block of this size would consume so long a period of time that long before complete radiation could take place the volume of heat would have accomplished work in the form of metamorphism.

With these data in mind, two important deductions will follow axiomatically, and these in turn will explain, logically, two phenomena before mentioned.

1. The disappearance of mineralization and metamorphic phenomena at or near an open fissure or a zone of crushed rock.

2. The phenomenon of a thin vein, lying between wholly unmetamorphosed strata, which, followed under cover, leads into a great blanket or manto or highly metamorphosed rock strata which may or may not be mineralized. The explanation on these lines is very simple.

In Fig. 71, let stratum $4'$–$4''$ be bent from the horizontal into the arc here shown. The heat developed by friction will, primarily, be distributed in the following manner: At $4''$ there will be no motion, therefore no rise in temperature. At $4'$ the temperature will be at the maximum. But $4'$ is exposed to the air with consequent rapid heat loss. The zone of effective heat will therefore approximate to the manto or blanket V–V'–z. Metamorphic action, owing to rapid radiation at $4'$, would be only slight at this point, while at $4''$ it would be wholly wanting owing to the non-generation of heat.

It may be remarked in passing, that the manto here outlined would be raised to a temperature of over 1,300° F., and that under conditions here set forth the entire volume of heat would be available for metamorphic work.

Were open fissures or zones of crushed rock developed along the lines E–F, C'–C'' or C'–K', it is evident that four distinct mantos or blankets would be formed in response to conditions already pointed out.

In conclusion, it is hardly necessary to state that only the ele-

ments of rock folding phenomena have been pointed out. A few examples only have been briefly elaborated. It is hardly necessary to call attention to the fact that while the fundamental principles involved are simple and capable of exact mathematical expression, the application of these principles is altogether a different matter. The time period of folding, the resistance of rocks to a crushing force, the direction and intensity of the forces involved, all these and many other elements are variables. Yet with all these exactly indeterminate factors, if one keeps in mind the fundamentals involved, the degree of variation in any or all indeterminates can be so reduced as to render the solution of any special problem close to safe economic limits.

I can safely say this: In an experience of practical economic geology reaching over a period of twenty-one years, I have found no theories which so satisfactorily solve so many economic geological problems as the ones here briefly set forth.

The only work which I have seen which touches this phase of geology is " Physics of the Earth's Crust," by the Rev. Osmond Fisher, published by Macmillan & Company, in 1881. This work is, however, purely scientific, and, in the main, inapplicable to the problems of the mining geologist except in the most general way.

PETROGRAPHIC NOTE ON THE DIAMOND-BEARING PERIDOTITE OF KIMBERLEY, SOUTH AFRICA.

VICTOR HARTOG.

WITH A BIBLIOGRAPHY OF THE SUBJECT BY A. A. JULIAN.

When first called on to assume the duties of surveyor at the De Beers mine in South Africa the writer of this paper felt that so much attention had been given to the petrographic study of the diamond bearing peridotite that little of value could be disclosed by further examination.

During a stay of three years, however, at the mine, from a careful comparison of published descriptions of the diamond-bearing rocks with the facts disclosed by personal observation it appeared that, although the mineralogy had been described in some detail little attention had been paid to the microscopic examination of the rock and many features of seemingly very considerable importance had been passed without mention.

Under these circumstances, though presented with some diffidence, the present notes on the petrography and bibliography seem warranted. It is to be regretted that the study could not have been extended to all of the South African pipes but it is believed that the present description will add something of material value to our present knowledge of the subject.

INTRODUCTION.

The investigation was based upon sixty specimens of peridotite taken from the north, south, east, west and center of certain working levels in the De Beers Mine, Kimberley, South Africa. Beginning with the 1,560-foot level, five specimens, duly marked N., S., E., W. or center, as the case might be, were collected every 40 feet down to the 2,040-foot level. The investigation thus extends over a vertical range of 480 feet. Most of the slides cut held together, indicating that alteration had not gone so far

as to produce crumbling. This difficulty had always been experienced in previous attempts to prepare thin sections from this rock, and for that reason only material from the lowest levels in the mine was selected.

LOCATION.

The diamond mines, which are known as the De Beers, Kimberley, Bulfontein, Wesselton and Du Toit's Pan, lie between longitude 24° 45′–24° 50′ E., and between latitude 28° 42′–28° 45′ S. They are distant 647 miles from Capetown and 485 miles from Port Elizabeth. The elevation is about 4,000 feet above sea level. The De Beers Mine is in the municipality of

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proved to be 10 acres. The peridotite pipe is more or less oval in plan, narrowing toward the west end of the mine.

The other mines are similar in shape, though perhaps they bear greater resemblance to a kidney or a bean. As far as it has hitherto been followed in the De Beers Mine the pipe has been found to stand practically vertical.

SUCCESSION AND CHARACTER OF SURROUNDING ROCKS.

The De Beers Mine main rock shaft passes through the following strata in descending order,

1.	3	feet red soil.
2.	63	feet basalt.
3.	204	feet shale.
4.	385	feet melaphyre.
5.	722	feet quartzite.
6.	540	feet amygdaloid and quartz porphyry.
Total	1,917	feet.

FIG. 74. Micro-drawing of peridotite, deeply serpentinized, × 70 diam.; *O*, olivine *A*, antigorite, scale serpentine; *S*, serpentine apparently massive; *G*, garnet; solid black, magnetite.

Below is granite of unknown thickness. It is impossible at present to say definitely that the eruption of the peridotite had any very marked influence upon such an easily altered rock as black shale. This shale has indeed been very much baked and altered, but then it must be remembered that the shale is overlain by a thick sheet of basalt. In its upper reaches it has turned all shades from white to brown, due to contact with the basalt sheet, and all that can be said about the influence of subsequent volcanic activity upon it is, that in the west end of the mine it is violently upturned. At this point, moreover, the shales come completely up to the surface, so that the basalt sheet is absent altogether.

The evidence of four separate and distinct eruptions seems to supply a reasonable explanation of the kidney or bean shape of the crater in plan, since a single outburst would probably result in a circular or oval crater.

The granite is found in the De Beers shaft at 1,920 feet from the surface, or about 600 feet higher than in the other shafts, making the volcanic series only 540 feet thick instead of 1,070 feet as at the other mines.

A summary of information obtained in mining operations at the four mines, Kimberley, De Beers, Bulfontein and Du Toit's Pan, indicates the following strata, given with minimum and maximum thickness.

Minimum Thickness.		Maximum Thickness.
2 feet.	Soil, calc. sinter and débris.....	30 feet.
18 feet.	Basic igneous series, basalts and dolerites....	63 feet.
200 feet.	Upper Dwyka shale	250 feet.
3 feet.	Dwyka conglomerate	10 feet.
0 feet.	Intermediate igneous series	394 feet.
82 feet.	Pre-Cape quartzites and shales	722 feet.
	Acid igneous series with basic dykes	1,070 feet.
	Granite and gneiss.	

If the shale belongs to the Karroo series, as has been suggested by Rogers, a great interval of time must have elapsed during which the igneous series was being poured out, since

there is a great gap in the succession below the Karroo series. It is evident that the basic series of volcanic rocks belongs to a much later period than the acid and intermediate.

NATURE OF THE PERIDOTITE.

To say that the peridotite itself varies greatly in composition and microscopic character, would convey but a poor idea of the startling varieties of composition and structure, which such a large body of eruptive has assumed after passing through all the surrounding rocks which have been mentioned and including so many fragments of them. It is stated by Gardner F. Williams that the peridotite was strangely enough found level with the surface at the De Beers mine. In the absence of any more conclusive proof we can therefore say that it is younger than the whole series, even including the overlying lateritic red soil which was probably derived from the basalt. After leaving the zone of the melaphyre the pipe extended upwards in the shape of a funnel, due to the diminished resistance offered to its passage by the shale and basalt.

Large masses of shale and basalt having undoubted close connection with the country rock, were found lying in the peridotite in the early stages of mining, and these "horses" are still occasionally met with in the lower reaches. The effect of heat on the black shale fragments has been to indurate them and slightly round off the corners. There is not much evidence of oxidation of the carbon content, which is easily understood when we think of complete immersion of such fragments and consequent exclusion of air.

The brecciated appearance of some portions of the peridotite *in situ* may be ascribed to the presence of numerous fragments of all of the rocks mentioned. The ground mass, however, has in no case substantiated the view that the igneous matrix itself is brecciated, since it is crystalline, though very much altered. Besides the numerous fragments already mentioned as being present in the pipe, rounded nodules of lherzolite, saxonite and eclogite are numerous, and from their zonal structure indicate segregation from a similar magma to the peridotite.

PHYSICAL CHARACTER OF SPECIMENS EXAMINED.

MACROSCOPIC CHARACTERISTICS.

Texture.—In nearly every case the texture in the hand specimens is found to be predominantly porphyritic, with crystals of olivine in a matrix apparently resulting from their own decomposition (1,960 N., etc.);[1] in some cases this texture being very fine grained (1,880 N.). Exceptionally a granitoid texture was observed (1,800 E.). The apparently normal, original peridotite was preserved in thin streaks (1,840 N.) or even constitutes the entire material (2,000 C.), being hard and fine-grained with few enclosed fragments. Weathered surfaces on the specimens are roughened by projection of the more resistant minerals, garnet, etc.

Color.—Some specimens are light colored (1,640 W. and N., 1,680 E., 1,760 E., 1,800 C., 1,840 N., 1,880 N.), sometimes light yellowish green spotted with black shale fragments (1,680 W., 1,720 N.). In most cases they are hard, dense, and dark green (1,640 S., 1,760 S., 1,680 C., 1,840 C., 1,880 S. and W., 1,920 S. and E., 1,960 N., S., C., W., 2,000 N. and C., 2,040 N. and W.). Some are greenish, softer and chloritic (1,960 E.); and then all the crystals appear to have been crushed and obliterated.

Inclusions.—Patches occur, apparently of a basic segregation (1,640 C.). Most of the foreign enclosures, however, consist of fragments of black shale which may be sparsely distributed (1,640 S., 1,800 C., 1,840 E.) or in abundance (1,560 C., 1,600 N. and W., 1,640 N. and W., 1,680 N. and W., 1,720 N. and E., 1,760 N., 1,800 E. and W., 1,840 N., 1,880 W., 1,960 E., 2,040 S.); occasionally these are found altered to hornstone (1,640 C., 1,800 N.). Other foreign enclosures consist of fragments of sandstone (1,560 C., 1,720 E., 1,800 E., 1,920 C.) and of igneous rocks (1,720 C., 1,840 C., 1,880 N. and W., 1,920 E.).

[1] These numbers refer to the location of the specimen in the mine. The figures give the levels where the specimens were obtained and the letters the north, east, south, west or central parts of the mine. These specimens have been donated to Columbia University and are on file in the Geological Museum.

Phenocrysts.—The olivine phenocrysts are the most prominent of the minerals in the hand specimens. These may be for the most part fresh (1,760 S., 1,840 W., 1,880 S., 1,920 N., S. and E., 1,960 W. and S., 2,000 N.), lying in a dark blue-green matrix (2,040 N., E. and W.); some are glassy green (1,720 E.). In some only a slight alteration into serpentine appears (1,640 S., 1,800 W.); others are so much altered that the original outlines of the crystals are lost (1,500 N., 1,600 S.,

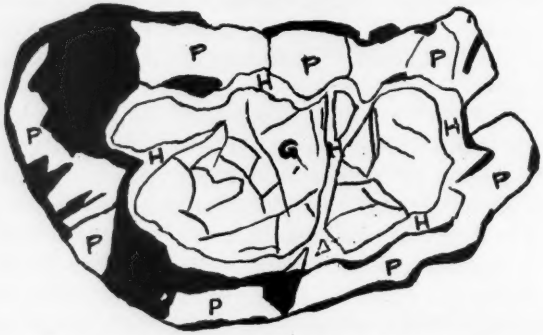

FIG. 75. Micro-drawing of garnet with a vein of phlogopite; × 70 diam.; *P*, phlogopite; *G*, garnet; *H*, vein of limonite; solid black, magnetite.

1,680 E., 1,720 N. and C., 1,760 N. and W., 1,800 N., 1,840 N., 1,880 N., 1,920 C., 1,960 E. and W., 2,040 S.). In some cases deep alteration borders surround beautiful, fresh, glassy-green cores (1,600 E.). By deeper alteration the whole rock becomes stained yellow (1,680 S., 1,720 S.).

Diopside appears in large green crystals (1,920 E., 1,960 C.).

Bronzite may occur in considerable quantity (1,680 W.).

Phlogopite is abundant (1,640 W., 1,680 S. and C., 1,800 N., 1,880 S., 1,920 N., 1,960 W. and C.), sometimes in plates 2 inches long (1,840 W.).

Biotite may be common (1,600 N., 1,680 E.).

Garnet (pyrope) is often prominent (1,560 N., 1,600 N. and C., 1,680 E.).

Calcite is abundant as a secondary accessory (1,680 S., 1,720 C. and E., 1,760 E. and W., 1,840 C., E. and W., 1,880 W., 1,920 N. and E.), sometimes in cavities which appear to have been once occupied by olivine crystals (1,920 W., 2,040 E.).

Dolomite is also secondary, probably derived like the calcite from weathering of olivine (1,720 E.).

Some brecciated specimens occur whose structure has apparently resulted from the shattering and recementing of a portion of the original peridotite (1,560 E., 1,600 C. and N., 1,680 C., 1,800 S., 1,880 C. and E.), occasionally into a very fine-grained micro-breccia (1,720 C., 1,760 S. and C.). In these also enclosures of foreign fragments may occur, consisting of shale (1,560 E.) in part altered to hornstone, sometimes the inclusions being other igneous rocks (1,680 C., 1,880 E.). Olivine may be represented by large fresh crystals (1,560 E., 1,800 S.), mostly replaced by serpentine (1,600 C., 1,640 N., 1,680 N., 1,880 C.). Phlogopite exhibits large plates (1,680 C.).

MICROSCOPIC CHARACTERISTICS.

The accompanying microscopic drawing will illustrate the descriptions that follow. The following minerals were determined:

Olivine.—Olivine in crystals, many of which are fresh with clear and sharply defined outlines, sometimes octagonal (1860 C., 1,680 C. and W., 1,760 E., 1,840 C., 1,920 E. and W., 1,960 W., 2,040 W.); sometimes shattered into many fragments (1,720 N., 1,920 W.). Its alteration into serpentine sometimes occurs as an outer coating (1,600 S., 1,640 S., 1,800 S., 1,920 C., 2,040 N.) or zonal (1,800 W., 1,920 E.) or a deep brown border (2,040 W.), perhaps fayalite or hyalosiderite. Its boundaries may be rounded and resorbed (1,560 N.), with jagged outlines and deep embayments (1,720 S.) such as might result from crystallization out of a quickly cooling magma. The

interior may appear as an unaltered green kernel (1,880 E.) sometimes with a rim of magnetite imbedded in phlogopite (1,640 C., 1,760 C.), or it may be highly altered, showing bar and fibre structure (1,720 C.). In the larger crystals inclusions of many forms and sizes abound (1,800 S., 1,920 E. and W.), rod-like (1,800 W.), in part rutile (1,560 N.), pleochroic (1,560 N.), often consisting of chlorite (1,560 E., 1,600 E., 1,800 S., 1,960 E., 2,040 E.).

Most commonly the olivine is traversed by cracks parallel to the base, occupied by veinlets of chrysotile (1,560 N. and E., 1,600 C., 1,640 C., etc.) and serpentine (1,760 N., 1,800 S. and E., 1,960 N., 2,040 S. and E.), accompanied with separation of iron oxide, hematite and magnetite (1,720 N. and S., 1,760 W., 1,960 E.). The latter may occur in specks sharply marking the outlines of the original olivine crystals (1,560 N. and C., 1,600 S., 1,800 S., 1,840 C., 1,880 W., 1,920 N. and E.). The completion of the alteration into antigorite pseudomorphs is common in the smaller crystals of olivine (1,560 W., 1,760 C., 1,800 S., 1,840 C., E. and W., 1,880 N., C. and E., 1,920 E., 1,960 E. and S.). A few crystals are converted entirely into chlorite (1,560 W.).

Monoclinic pyroxene occurs in crystals containing inclusions (1,560 E., 1,720 E., 1,920 N., 1,960 W., 2,000 N.), and is sometimes abundant (1,800 E., 2,040 W.). These may be so crushed as to present a mosaic effect, extinguishing in patches (1,600 W.) and otherwise altered (1,800 S.).

Bronzite may appear in numerous crystals (1,960 W.) but is more commonly represented by its altered form, bastite (1,960 N., 2,000 N., 2,040 E.).

Amphibole is found in prominent crystals (1,760 S., 1,880 E.), sometimes more abundant than those of olivine (1,720 E.).

Phlogopite occurs in plates with distinct cleavage and pleochroism (1,880 W., C. and E.), sometimes borad (1,560 N., 1,680 C., 1,760 C.) or long and thin (1,800 S.), scattered or in bunches (1,720 S.), and commonly in abundance (1,600 W., 1,640 N., 1,720 E., 1,760 N., 1,800 C.). Its borders may show

resorbed outlines (1,920 W.), deeply embayed (2,040 E.) dotted by iron oxide or with deep reaction rims (1,840 E.). The plates reveal the effect of pressure by wavy extinction (1,560 E., 1,720 S., 2,040 S.), or may be crushed and bent (1,560 W., 1,720 S., 1,800 N., 1,840 C.) or even much strained and twisted (1,880 W.).

Biotite, with good cleavage, is abundant (1,600 N., 1,840 E.) in large plates (1,600 C., 1,760 C.), showing wavy extinction (1,920 C.); their borders may be resorbed (1,880 S.) or dotted with magnetite particles (1,600 E.).

Muscovite (talc?) may occur in a much altered scale (1,760 C.).

Chlorite abounds in some sections (1,800 S., 1,880 N., 200 N. and C.) or as inclusions in olivine crystals (1,560 C.).

Orthoclase may occur in a few crystals (1,600 S., 1,640 S.).

Garnet, probably an iron-magnesium variety, often appears, showing phlogopite in cracks (1,680 W., 1,600 E., 1,760 E.), surrounded by crossing horns of plagioclase (1,600 C., 1,960 C.); sometimes in the form of isometric crystals with dark reaction rims (1,600 C., 1,960 C.) or completely altered (2,040 N.).

Quartz is always a secondary accessory (1,600 S.), generally associated with a zeolite (1,560 N.).

Iron oxides, chiefly magnetite and hematite, may occur in particles dotting the borders of altered crystals of olivine or the veinlets subdividing them into patches (1,920 N., 1,960 S. and C.), or present in such abundance as to darken the section (1,680 S., 1,800 C., 1,880 N.).

Magnetite is particularly plentiful in many specimens (1,640 N., 1,880 E., 1,920 C., 1,960 S. and C.), though in some others rare (1,840 E.) and apparently due to decomposition of olivine (1,560 N.).

Ilmenite also occurs in characteristic gridiron forms and with very striking etched appearance (1,560 C.).

Deweylite may constitute radial clusters which remain dark between crossed nicols (1,560 E.).

Zeolites, in company with quartz (1,560 C.), indicate the later

circulation of thermal waters. These occupy numerous cracks (1,560 N., 1,640 S., 1,720 E.) and many cavities (1,800 C., 1,840 C.).

Perofskite is common, sometimes in large amount (1,880 S., 1,920 E., 1,960 S.).

Corundum (?) may constitute small blue anisotropic grains (1,880 N.).

Calcite, derived probably from breaking down of pyroxene, occurs in cracks of the section (1,560 N., 1,880 N., 1,920 N. and C.) and cavities (1,840 C. and W.), sometimes in abundance (1,800 W.).

Siderite (?) is found in small rhombs, with nuclei of magnetite.

Apatite was also noticed.

Enclosed Fragments.—The foreign enclosures observed under the microscope in the thin sections consisted mainly of fragments of black shale whose borders are smooth and rounded (1,560 W., 1,800 N.), resorbed or fused (1,560 N.), or with reaction rims (1,600 E.). A zonal arrangement sometimes appears, consisting of the following four bands around the black interior; deep ochreous, colorless, milky white, and on the outside a coating resembling serpentine (1,560 N.). An extreme form of the alteration may be shown in certain opaque spots (rendered so by carbon?) mixed with serpentine (1,760 C.). Some of these fragments on thin edges of the sections (1,560 N.) were examined under the highest power for diamonds, but none were found. A form of alteration of the shale appears in fragments of hornstone distributed through the rock (1,680 C., 1,720 S.), as well as secondary silica and chalcedony. The decomposition and alteration seem to have terminated with silicification. Igneous rocks also constitute some of the foreign fragments (1,720 C., 1,960 E.).

Groundmass.—The groundmass in the thin section sometimes appears finely crystallized, made up of minute but distinct particles (1,760 S., 1,880 S.), which can sometimes be recognized as elongated or lath-shaped crystals, in irregular bundles or without definite arrangement (1,600 E., 1,720 C.), with the

extinction of feldspar (1,560 E.). More frequently, however, the original structure is lost (1,560 N., 1,600 S., 1,640 C. and N.) and the groundmass appears to be made up entirely of the products of alteration of olivine (1,760 N., 1,800 N. and W., 1,840 W., 1,880 W.). Through this the following minerals were made out.

Olivine in minute crystals, all with altered rims or altered throughout.

Magnetite, often in large amount, in secondary particles (1,600 E., 1,640 S., 1,680 C., 1,720 N. and E., 1,760 N., 1,800 N. and W., 1,840 C., 1,880 S., 1,920 W., 2,040 N.

Amphibole, secondary, in needles irregularly oriented (1760 E.).

Spinel, in occasional crystals (1,880 S.).

Perofskite, in small translucent crystals with very high relief (1,600 S. and E.), sometimes so numerous as to color the field brown (1,880 S.).

Shale, in very minute, abundant fragments (1,720 N.).

CHEMICAL CHARACTER OF "BLUE GROUND."

The following analyses from the De Beers mine at Kimberley will illustrate the character of the blue ground:

1. Least decomposed, with few shale enclosures. S.G. = 2.734. Analyst, H. C. Lewis.
   (*a*. Silica—includes over 1 per cent. of titanic acid;
   b. Ferrous oxide—includes alumina;
   c. Loss includes carbonaceous matter.)
2. More decomposed, with many shale enclosures; diamantiferous. S.G. = 2.64–2.70. Analyst, H. C. Lewis.
3. Blue Ground. Analyst, Maskelyne.
4. Blue Ground. Analyst, L. de Launay.
5. Friable, earthy, greenish-blue rock diamantiferous. Analyst, H. E. Roscoe.
6. Hard rock. Analyst, L. de Launay.
7. Hard rock. Analyst, L. de Launay.
8. Compact, greenish-gray, hard rock. Analyst, H. E. Roscoe.
9. Rock of Bulfontein. Analyst, Maskelyne.

	1	2	3	4	5	6	7	8	9
Silica	33.00[a]	34.80[a]	39.73	40.30	46.16	46.60	49.50	58.03	20.70
Alumina			2.31	9.45	10.00	16.90	18.40	15.53	.55
Ferric oxide / Ferrous oxide	12.00	14.40	9.69	7.30	6.71	11.60	13.10	9.64	4.30
Manganous oxide					.34			4.54	
Magnesia	32.38	30.76	24.42	21.20	16.63	9.35	5.25	4.55	5.80
Lime	9.60	2.70	10.16	3.48	3.84	2.87	2.24	6.99	.52
Potassa				.90		.63	1.48		
Soda	0.67	1.40		4.93		4.67	4.65		
Loss at 120° C.					9.75			0.00	
Loss at red heat	6.00[c]	10.60[c]	7.55	13.00	5.68	7.12	5.23	0.00	undet.
Carbonic acid	7.05	5.55	6.56	undet.					
Lime carbonate									59.63
Magnesia carbonate									4.97
Ferrous carbonate									3.02
	100.70	100.21	100.42	100.56	99.11	99.74	99.85	99.28	99.49

SUMMARY OF CHARACTERISTICS.

In summary the following constituent minerals were identified: Olivine, fresh and unaltered; amphibole and pyroxene, including diopside; bastite; phlogopite; garnet; perofskite; magnetite and ilmenite; apatite, tremolite and rutile; serpentine, calcite, chlorite, spinel zeolites and chalcedony.

The rock was found in nearly every case to be porphyritic, the phenocrysts being olivine predominantly. In some of the slides large altered crystals of orthorhombic pyroxene are present. The original unaltered rock might well have been almost all olivine, judging from the large amount of serpentine present in every case. Alteration of olivine and pyroxene in all their varieties is well seen throughout from veinlets of chrysotile formed in the cracks, to complete replacement by serpentine. In some cases bastite has completely replaced the original bronzite crystals. While a few of the hand specimens seem to show brecciation this structure could not be confirmed in the slides cut from them. The whole series of specimens is, however, too decomposed to allow the original structure of the ground mass to be seen with any degree of certainty. The olivine crystals are often rounded and embayed and contain rutile and magnetite, preserving the original outlines in cases where decomposition has begun.

The ground mass is fairly homogeneous and consists mainly of serpentine resulting from the breaking down of the original olivine. Through it are scattered chromite, magnetite, garnets, and ilmenite. Under a high power the fresher portions consist of prismatic crystals, whose character was not determined. Among the inclusions in the peridotite the black shale fragments are by far the most numerous. They exhibit signs of alteration on their borders by the heated magma, though this alteration is not very marked or extensive. Fragments of sandstone, gneiss, granite-porphyry and eclogite can always be seen in the peridotite in the mines, and often small fragments of these appear in the hand specimens.

PREVIOUS WORK ON THE SUBJECT.

Professor H. N. Lewis recognized three varieties of kimberlite (the name proposed for the diamond-bearing peridotite):

1. Kimberlite proper, a typical porphyritic lava.
2. Kimberlite breccia, the same lava broken and crushed by volcanic movements, and crowded with included fragments of shale.
3. Kimberlite tuff, being the fragmental tufaceous portion of the same rock.

During his connection with the De Beers C. M., Ltd., as surveyor, from 1901 to 1904, the writer had constant opportunities for seeing the varieties which existed in the peridotite, from level to level, and also on the same level. The rock seems to suggest brecciation at once on account of the numerous foreign fragments which can always be seen. Although microscopic examination does not confirm this idea, it does not interfere with the possibility of such a true brecca being found in specimens from the upper reaches of the mine examined and described by Professor Lewis. Its pyroclastic nature was nowhere apparent under the microscope, but rather, in every case, it seemed to indicate the characteristics of a purely volcanic rock in which there may have been subsequent movements. No evidence of flow structure was noticed, although the mica was

found bent and the olivine crystals often showed wavy extinction as the result of strain.

It is a well-known fact at Kimberley that those portions of the peridotite which are richest in fragments of black shale are considered to be also richest in diamonds. While this relationship has suggested the idea that the carbon in the black shales supplied the material for the diamond, the supposed richness has not been officially confirmed. Yet it is a fact that the western portion of the mine, which is composed of a hard peridotite not readily decomposed and without shale fragments, is so poor in diamonds that it is no longer worked; on the other hand, we have a striking contradiction of the above theory in the Pretoria district of the Transvaal, where Dr. G. A. Molengraaf describes a fine pipe of kimberlite containing diamonds. At this locality it is well determined that there are no carbonaceous shales present either at the surface or in depth.

Mr. Gardner F. Williams mentions that on January 9, 1904, a diamond of 114 carats was found in Wesselton Mine, with a garnet imbedded in it weighing half a carat. A diamond has also been found containing olivine. Sir William Crookes has noted that the ash from impure diamonds always contains iron. H. S. Harger thinks that, owing to the intimate association of diamond with garnet and ferromagnesian silicates, it had its origin in a very deep seated ultra-basic zone. Dr. Friedlander showed that the diamond can be formed in olivine without the enormous pressure and heat used by Moissan. In seeming opposition to all of these suggestions we have the startling experiment of Herr W. Luizi, of Leipsic, who heated the peridotite to 1,770° R., when it deeply corroded a smooth diamond placed in it.

Waldemar Lindgren, who studied forty-five slides supplied by Mr. Gardner F. Williams, is of the opinion that the diamond was evidently contained in the peridotite magma and crystallized with it.

Herr Luizi's experiment no doubt is a criterion of what would happen to the diamond in its present matrix at the temperature

he used, and at atmospheric pressure; but a very different result might have been obtained were the pressure and temperature to approach those used by Moissan.

While the pros and cons of the theory of diamond formation in nature are found to balance each other in such a way as to lead to no certain conclusion, the origin of the gems in a particular magma must be purely speculative.

As to the peridotite itself the writer is of the opinion that it is an ultra-basic eruptive, not a breccia since its porphyritic crystals are idiomorphic. They are corroded in some cases by the molten magma. There is a true ground mass, although this is much decomposed and often indistinguishable. The rock is similar to the Kentucky peridotite which is a dyke rock. The brecciation described by Professor Lewis is quite likely and possible in such a rock, under such conditions, but has not been noticed in the slides considered. The writer is the more convinced of this possibility on account of the evidence of separate eruptions in the same crater, leading to the familiar kidney or bean shape of the funnel, as against the elliptical outline of a crater produced by one outburst.

Nothing need here be said about the characters of the diamonds from the five mines under discussion except that they vary greatly in size, color and shape. This in itself, however, is no proof that they did not have a common origin.

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DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

THE ORIGIN OF THE RAND GOLD FIELDS

DISCUSSION IN CONNECTION WITH PROFESSOR GREGORY'S PAPER

Sir: I was fortunately present in London at the reading of Professor Gregory's original paper on "The Origin of the Gold of the Rand Gold Fields" and contributed some remarks in the after discussion upon the paper, in which I supported Professor Gregory's views as to the origin of the gold in the banket formation. I also had the pleasure of showing Professor Gregory over some of the interesting mines of the Rand with which I was then officially connected, and to have furnished him with certain specimens, data, assays, etc., in connection with his investigation.

The subject of the source of the gold associated with the Rand beds has been fruitful of many theories, and has been traversed periodically with more or less thoroughness by the exponents of these varying theories during the past twenty years. Out of the maze of theories two major schools have evolved, namely, (1) those who hold that the pebble beds have been enriched by infiltrating solutions—to which we will refer as the "infiltrationists"; (2) those who regard the whole deposit as a marine placer in which the gold, arenaceous particles and pebbles were contemporaneously deposited, to which we will refer as the "placer" theorists.

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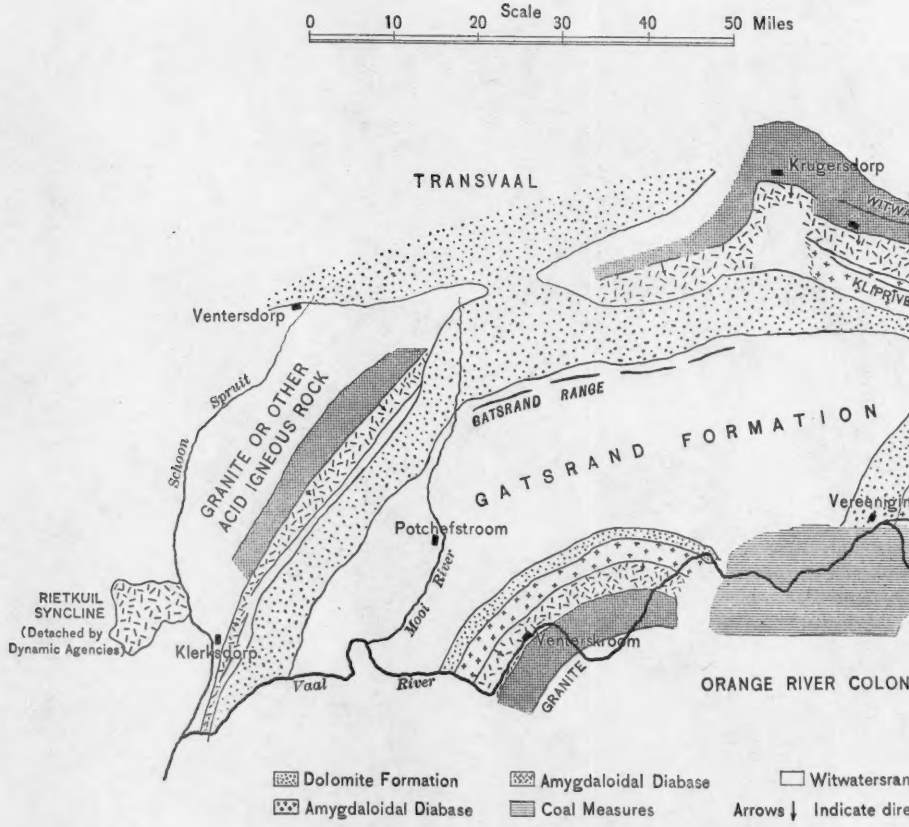
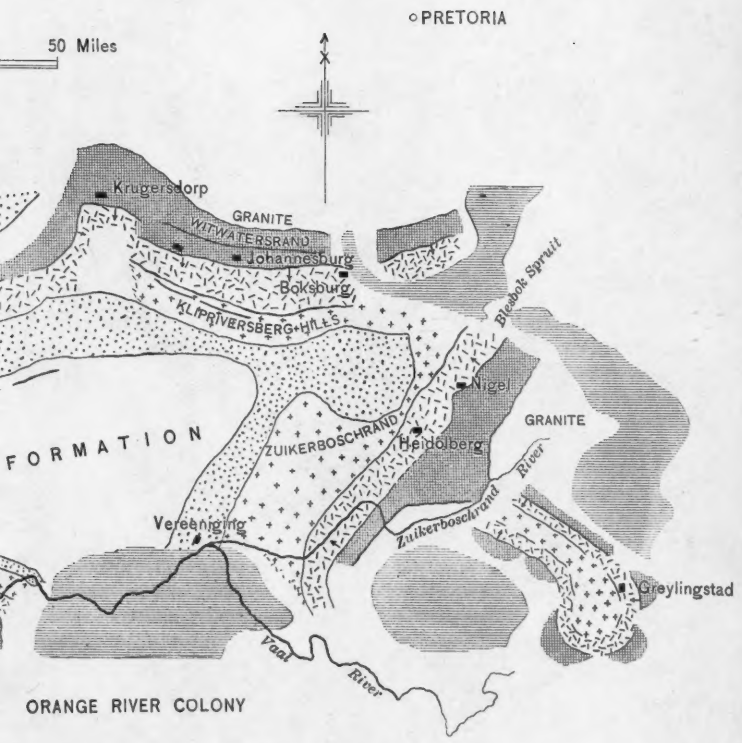


FIG. 76. Geological Map of the Transvaal.

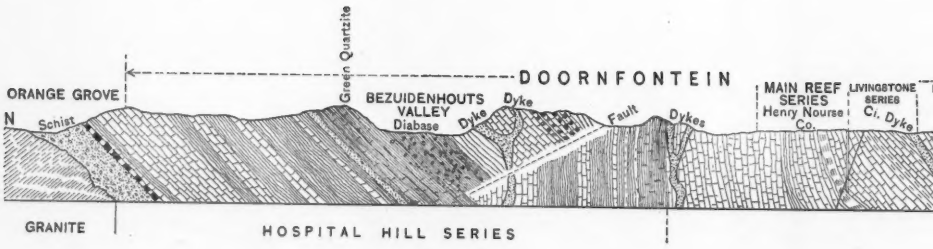


base ☐ Witwatersrand Beds ▨ Quartzite Shale Group

Arrows ↓ Indicate direction of dip

al Map of the Transvaal.

PLATE VI


Green Quartzite
DOORNFONTEIN
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N
Schist
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Henry Nourse Co.
LIVINGSTONE SERIES
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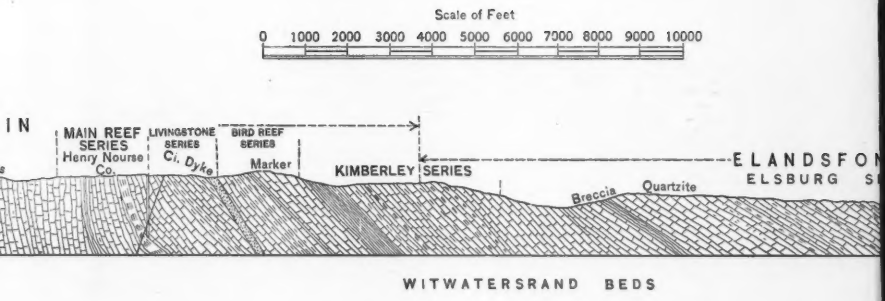
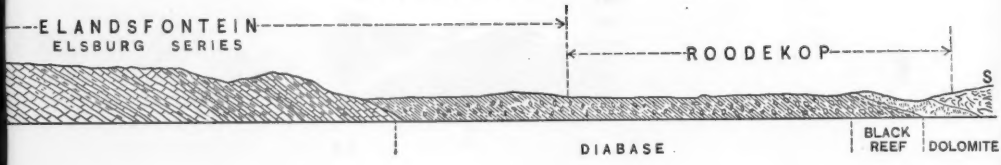
GRANITE
HOSPITAL HILL SERIES



CROSS SECTION OF THE RAND GOLD DISTRICT, LOOKING EAST.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BLACK REEF
DOLOMITE

AST.

Perhaps it may be well at the outset to state some facts concerning the distribution of the Witwatersrand formation. The accompanying geological map, Fig. 76, may serve to make the description clear. The Transvaal banket deposits are not confined to the Witwatersrand district. They occur, amongst other places, over large areas in the Klerksdorp district, one hundred miles west of Johannesburg; in the Heidelberg district, to the southeast of Johannesburg, and on the eastern border of the colony; in the Vreyheid district. In each instance the geological conditions and the mineralization are identical.

The Witwatersrand area proper may be included within the limits of Randfontein, twenty-five miles west, and Benoni, twenty-five miles east of Johannesburg, whilst the thickness of the sediments, from the quartzites underlying the main reef to those overlying the Kimberley reef, may be taken at three fourths of a mile. The formation is essentially quartzitic, and contains several series of banket layers, the principal of which are classed, beginning with the oldest, as the Main reef series, the Bird reef series and the Kimberley reef series. The thickness of quartzite separating the three is approximately 1,600 feet from the upper member of the main reef series to the lowest of the Bird reef series, and about an equal thickness between the upper member of the Bird reef series and the lowest of the Kimberley series. The attached cross-section, Plate VI., through the central Witwatersrand will convey an idea of the geological conditions and stratigraphical relations.

An enunciation of the infiltration theory might be made in the following terms: Anterior deposition of the pebbles and arenaceous matrix; subsequent infiltration of solutions carrying gold and iron sulphides from other formations through the partially consolidated conglomerates; and final precipitation of the gold and iron sulphides amongst the mass of silicious material.

This theory when applied to the conglomerates of the Witwatersrand appears to the writer to require a greater stretch of the imagination than is warranted by the apparent conditions. In accepting it as the most probable explanation of the gold and

pyritic contents of the banket beds, we must postulate the following conditions:

1. A mass of rounded pebbles and quartzitic sand particles forming a stratified portion of an already consolidated crust, but in such a condition that there are interstitial spaces for the flow of solutions.

2. An enormous area, say from Klerkstorp to Heidelberg, roughly 130 miles in lateral extent, and say 5,000 feet in vertical thickness, in which there was such uniformity of conditions that circulating subterranean waters could permeate more or less evenly the entire area and precipitate their metallic contents amongst the pebbles and quartzitic material forming the conglomerate beds of one certain horizon, practically neglecting the still porous sand-like sediments and the conglomerate beds of later deposition, which, owing to the nature of their constitution, should theoretically be of greater porosity than the beds of the older horizons.

3. An enormous thickness of sedimentary formation embracing a vertical measurement of 5,000 feet, in which solutions have displayed selective action in conditions which apparently do not favor such.

4. A succession of conglomerate beds, all of one geological period, and practically identical in all respects—stratigraphically, petrographically and mineralogically, which have shared the same vicissitudes of fold and fracture and are ramified by dykes of igneous rock of the same age. Of these, only the lowest series of beds, however, have been permeated by highly charged metalliferous solutions—or if the others have been so charged the requisite precipitant for the gold has been wanting—and, therefore, to-day we have the spectacle of the lowest member of the series only to have been proved auriferous to such a degree, and over such extent as to make the extraction of the precious metal commercially profitable. At the same time, the proportion of iron sulphides is probably considerably greater in some of the younger beds than in the older.

To come to particular instances. In the New Goch Mine, formerly under the writer's control, there exists the rather unusual

feature of a great mass of pebbles approximating fifty feet in thickness, at some points, lying immediately under the main reef leader. This so-called Bastard reef consists of loosely agglomerated pebbles and brecciated lumps of quartz and quartzite, very pyritic at points, but generally sparsely mineralized. The main reef leader lies almost without distinctive parting on this pebbly mass, but is unlike it in every particular. The pebbles are smaller on the average and thickly set with iron pyrites in a glassy cementing silicious medium. It is often, though not invariably, rich in gold, assaying up to 100 ounces per ton on narrow widths, whilst the bastard reef, divided by a line of demarcation, not thicker than a knife's blade, contains only traces of gold. The main reef, in the particular section of the mine in the writer's mind, contains gold of an average of 10 pennyweights per ton on a width of three or four feet. Immediately overlying is the bastard reef, containing traces only, and lying in contact with the bastard reef is the main reef leader, assaying perhaps six ounces of gold per ton on a width of six inches. It is surely awkward for the infiltrationists to assert on the one hand the porosity of the pebble beds to be the direct cause of their enrichment, and at the same time to be compelled to admit that the most porous of three given layers has been to all intents and purposes untouched by the percolating solutions, whilst the less porous have been enriched.[1]

No less at variance with the deductions of the infiltrationists are the actual conditions at the Van Ryn Mine. The South reef

[1] For the benefit of readers unacquainted with the Rand it may be stated that the Main Reef series is divided into three bands of quartz conglomerate called the Main Reef, the Main Reef Leader and the South Reef. The Main Reef is the lowest member of the series and averages perhaps four feet in width. An intervening band of quartzite from two to twenty feet in width separates the Main Reef from the Main Reef Leader, the latter averaging perhaps two feet in width. Lying above the Main Reef Leader is a thickness of quartzite, which includes the bastard reef, from twenty to fifty feet in width, when comes the South Reef, having an average width of perhaps three feet. These figures are merely approximations, as the variation in the thicknesses of quartzites separating the reefs is very great in the different sections of the field. In the central Rand, for instance, the whole three reefs may occur within a width of fifty feet, whilst on the Western Rand the distance extends to 150 feet, and on the Eastern Rand the distance may be up to 500 feet.

and main reef in this mine are the widest of the reefs of the series, and the latter lies upon a schistose rock, from which it is usually separated by a vein of white quartz from six to twelve inches in width. The plane separating the foot-wall schist from the overlying pebbly main reef must have been one peculiarly adapted for the passage of percolating solutions and we should expect to find that along this plane and in the reef matter adjacent there would be the richest concentration of gold in the region. As a matter of fact the main reef is on the whole poor in gold and the secondary vein quartz between it and the foot-wall schist, often as high as two feet in width, contains no gold. The enrichment in this area is found along planes in the quartzites, lying anywhere from ten to fifty feet above the main reef, in what are known as the main reef leaders. In these leaders there are frequently for distances which can be expressed in feet no pebbles at all, then an isolated pebble appears, and where the pebbles are thus found they are encased in a fine arenaceous material so rich in gold that not to find coarse particles of visible gold is rather the exception than the rule. The South reef, which is by far the widest body of the series, is so poor, that all work on it was abandoned over 10 years ago. The percolating solutions in this case again must have defied all usual laws and forced an entrance along the planes of greatest resistance, avoiding the easily accessible avenues in their paths. Going westward on the Rand similar difficulties appear. At the Roodpoort United Mine the Main Reef and Main Reef Leader are both comparatively large and well mineralized bodies, containing large sized pebbles, and to all appearance valuable ore. In general both reefs are too poor to work. The South Reef, on the contrary, lying up to a hundred feet above the Main Reef, in the quartzites, has a small pebble, averages less than one foot in thickness throughout the workings, is richest where it is only half an inch in thickness and poorest where it reaches a width, as it does in one section of the mine, of two to three feet. These instances can be repeated without number, not as covering isolated spots, but the whole region of large mines. It is inconvenient, and unfortunate also, for the infiltrationists that the ore

on either side of dykes should fail to afford any weight of evidence in support of their views. If solutions had been circulating through the sediments, they would have perforce been brought up sharply against the innumerable dead walls presented by the dyke systems of the Rand. The dykes have a thickness of from two feet to one hundred feet and they are innumerable throughout the mines on the field. Each forms an insuperable barrier to the flow of solutions, and therefore, unless every dyke-invaded area has been fed with its own special quantity of solution, we should find to-day one area within dykes, highly enriched, and another, in the same vicinity, similarly situated respecting dykes, but entirely barren of gold. But actually we find nothing of the sort. The writer, after a ten years' most intimate acquaintance with the underground conditions of many important mines on the Rand, can assert without fear of contradiction that in not a single instance could any satisfactory connection be traced between the dykes and the gold value in the reefs. Dykes can be found passing through the good ore shoots and the values on either side of the dyke are about similar, and equally, dykes can be found passing through low grade sections and the values on both sides of the dyke are apparently unaffected. There are instances in which ore is found richer on one side of a dyke than on the other, but this can be traced in every case in my experience to movements of the formation along the wall of the dyke, this movement bringing into apposition areas originally probably far removed.

Perhaps, however, the cases of the younger and therefore presumably more porous pebble aggregates known as the Bird Reef and Kimberley Reef, respectively, are more significant. These agglomerations are each approximately 500 feet in thickness; not all, be it understood, in one immense pebble bed, but rather alternating layers of pebble beds, grits and quartzites, throughout the thickness. The Kimberley Reef, it is true, is sufficiently rich in gold at one spot to have claimed the dignity of a full milling equipment, but otherwise has never yielded any payable ore, nor have any average values obtained from it by the writer exceeded three pennyweights of gold per ton. The Kimberley Reef is

characterized by its immense pebbles, far exceeding any that can be found in the Main Reef. The average Main Reef pebble, for instance, might be two inches in length through the longest axis, whilst the average Kimberley Reef pebble might be four inches, and along some stretches an area might be encountered having pebbles up to six inches along the greatest dimension. Pebbles of the latter size, excepting perhaps in isolated cases of the Bastard Reef overlying the Main Reef, are unknown in the Main Reef series. The Bird Reef is wholly a small pebble bed in which the average would not exceed half an inch in the greatest dimension. The infiltrationists, in urging porosity as essential to the validity of their theory, create therefore some curious situations. The Main Reef of the Main Reef series, having the biggest pebble and the largest mass of material, should be most easily percolable, and therefore the richest of the series. It is in fact the poorest. The South Reef of the Main Reef series has the smallest pebble, and particularly in the Roodpoort district, the narrowest width, and on general principles, following the infiltration theory, should be the poorest. It is in fact the richest. The Kimberley Reef with wide layers and immense pebbles is again richer than the Bird Reef with smaller layers and pebbles, thus transposing the conditions obtaining in the Main Reef series. The infiltrationists again argue that the gold in the banket beds affects only the cementing matter around the pebbles, whilst the pebbles themselves are barren. The pebbles are not always, however, barren. The writer possesses a specimen obtained from the Meyer and Charlton Mine, in which gold unmistakably occurs embedded in the heart of the pebble. That, however, in itself proves nothing, as it remains true as a general statement that the quartz pebbles are barren. But the same statement is equally true of recent placer deposits. Fragmentary angular quartz with attached gold nuggets the writer has many times seen from the wash of the deep leads of Ballarat, Australia, but cannot recall any case of gold being found in the pebbles or the wash. The alluvial miner does not expect it, nor does he look for it. He seeks for the gold in the material associated with the larger pebbles, exactly as is the case in the banket beds of the

rock, and if not found there its existence in commercial quantity is summarily dismissed. The claim of the infiltrationists that this feature of barren pebbles tells against the placer theorist is therefore unconvincing.

The argument that because the gold particles in the banket are not water-worn, but crystalline and angular, is well met by Professor Gregory's statement that the fine flakes of gold have been squeezed out of all shape by the intense pressure to which they have been subjected in a formation so old as that of the Rand banket. Mr. John Hayes Hammond, writing in Truscott's "Witwatersrand Gold Fields," says: "The Reefs contain, however, a considerable amount of gold of undoubted detrital origin, as proved by its water-worn appearance." The writer has recognized, to the best of his judgment, in some of the richest stringers in the Van Ryn Mine, quite unaltered rounded particles of gold, and other particles in the same specimen appear to be moulded over and round, rough surfaces of quartzite which were doubtless originally fragmentary quartz. It is not denied, however, by the placer theorists that secondary solution and re-precipitation of the gold has not occurred. On the contrary they agree that these agencies have been at work to some unknown degree within the Rand formation, precisely as they have operated in the clearer instances of say the Butte copper deposits.

I find it hard to yield the point even to Professor Gregory that the rolled iron pyrites of say the Black Reef are not indisputably a water-worn product. These pebbles of pyrites lie thickly clustered together, imbedded in an arenaceous base, and have none of the appearance or internal construction of accretionary forms. On the contrary, they are flattened, kernel-shaped forms, reaching half an inch in length, extremely hard and dense in constitution, and therefore able to withstand an ultimate reduction to granules. I have in my possession specimens from the banket which appear to be undoubted accretions, but they are in my opinion due to the secondary agencies previously referred to, and they differ in every respect from other pellets which I take to be of original detrital origin.

The infiltrationists use in support of their theory the premise

that the gold in the banket formation is uniformly distributed. I have many times wished the infiltrationists were sound in this regard when viewing the fluctuating results of development in a given mine, and the altogether inexplicable falling-off of yield from stopes counted upon to maintain a certain grade. I have stated before on various occasions, and now re-assert the statement, that in the Rand banket are to be found as violently fluctuating values as are to be found in any other form of metalliferous deposit. I have known a stope giving values of twenty pennyweights on stopping width, and one calculated to maintain its value, to suddenly drop to an average of five pennyweights. Any assay plan of the Rand will disclose the immense range of values of the ore in any given stretch. In the best section will be found side by side with assays of two pennyweights, values of five to ten ounces, and similarly in the poorest section may be encountered one or two high assays, as high as the highest yielded by the best stretches. A notable example of the irregularity of the gold values was shown in certain borings undertaken on the East Rand Proprietary Mines. This company operates some of the richest mines on the fields, nevertheless, out of some twenty bore holes that were sunk on the presently developed properties, to prove the value of the ore within certain areas lying close to the outcrop, if my memory serves me correctly, only one disclosed a value at all indicative of that which later developments revealed. The want of uniformity is well illustrated by Professor Gregory's reference to the unworked gaps along the Rand banket outcrop as impressive proof of the irregularity of the gold distribution. These gaps are particularly noticeable from the Crown Reef group of mines lying just to the westward of the town of Johannesburg, thence to Roodpoort, which lies about ten miles still farther to the west. In this stretch, until recently, there was hardly a producing mine which could be called a profit earner, even on the usual Rand practice of calling profits merely the difference between revenue and expenditure, and ignoring interest on and redemption of capital outlay. There are in fact even to-day less than six producing mines working along this entire stretch, whilst in the central section of the Rand, within a dis-

tance of two miles are to be numbered fifteen producing companies, embracing the richest mines in the fields. This is the impressive fact pointing to want of uniformity to which Professor Gregory so pertinently refers. There is in short no regularity whatever, unless it be irregularity. The basis of the Rand's reputation for uniformity is not equality of gold tenor, but range of development. Comparatively immense areas are laid under contribution for mill supply, and the possession of development over such wide areas permits a policy of selective stoping to proceed, by which ore of different values is drawn upon to maintain equality of output. Such a range of development also enables the engineer to forecast probable values and tonnages in a manner practically unknown in any other metalliferous field, not, however, in any sense due to the uniformity of metal content, but merely to such a purview of the value position, owing to the disclosures of great developed areas, that ores of different grades yielded by the mine can be mixed in such proportions as to yield at all times a definite average value.

Whilst denying, however, the uniformity of gold distribution claimed by the infiltrationists, I readily admit the difficulty of imagining the conditions governing such a wide geographical distribution of the gold in the banket. This distribution of the gold is, however, no more difficult to account for than that of the pebbly matter constituting the banket beds. They are one and the same problem. The South Reef, for instance, is recognized unmistakably as the "South Reef" from one end of the Rand to the other. It is hard to imagine in what circumstances the identity of one line of pebbles (not necessarily, of course, in one plane) could have been maintained for fifty miles of shoreline, and to the writer this ranks as a phenomenon no less wonderful than that within the pebble bed and as one of its essential constituents is the element gold, not uniformly distributed, as alleged by the infiltrationists, but of the most spotty character when commercially viewed.

Having now stated some difficulties which beset the acceptance of the infiltration theory, it is proposed to deal with the evidence

in support of the placer theory, enunciating briefly at the outset the various views held by the placer school.

1. A common origin for both gold and matrix. This theory premises preëxisting quartz veins which have been denuded and transported by natural agencies to a shallow sea. Here wave action has brought mechanical operations into force, tending to disintegrate and erode the more friable materials, whether of quartz or other rock, finally concentrating as a residuum only the denser rock fragments in rounded forms, interspersed in a base of pyritic granular material, the latter containing the gold particles originally present in the quartz veins, or other gangue.

2. Diverse origin of gold and matrix with contemporaneous deposition. This theory premises again the transport of fragments of eroded rocks into a shallow sea, and in the same period an ingress of iron sulphides and gold, these latter having been derived from agencies analogous to those which are responsible for the filling of fissure veins. It is not insisted upon that there would have been simultaneous deposition of the gold and pyrites with the pebbles and arenaceous matter, but that there is a probability of gradual deposition from a more or less concentrated solution; or that the deposition was caused by organic matter in the shallow sea.

3. The pebbles and some of the granular matter to have been derived geographically from a different position to that from whence the gold, pyrites and portion of the granular matter were disintegrated. This theory attempts to overcome the difficulty of explaining the almost entire absence of gold in the pebbles by assuming that the localities which supplied the pebbles, and those which supplied the gold, pyrites, etc., were probably geographically distant from one another, and that the commingling of the particles in the shallow sea was brought about by aqueous transporting agencies.

To all these theories there are many objectors who base their primary difficulty in accepting them on the fact that to all intents and purposes the pebbles in the conglomerate beds are barren of gold. But this is a feature quite as characteristic of tertiary alluvial deposits as of the banket beds, and therefore gives rise

to no differentiation of view as to the occurrence of the gold in the one or the other.

The drifted material throughout the ancient conglomerate beds of the Witwatersrand is composed practically of the same constituents, namely, pebbles of quartz and quartzite; an arenaceous base; pyrites; and, not necessarily, gold. The inference drawn from this is that the rolling and abrasion to which the material has been subjected by mechanical action has ground away all those materials which feebly resisted attrition, leaving only those which by virtue of their hardness were able to survive. There is, however, a very interesting, and as far as the writer is aware, quite unique exception to this general condition—as pointing to more quiescent localities in the sea bottom—in one portion of the Meyer and Charlton Mine. Here in the Main Reef, from the second to the fifth levels, and on a length of 500 feet, the quartz pebbles are wholly or in part represented by calcite, assuming, though not in all cases, the same rounded water-worn shapes and set in a cement which is almost wholly an admixture of calcareous matter and iron pyrites, together with quite high gold values. In many places there may be seen portions of the conglomerate bed in which the proportion of quartz and calcite pebbles are equally distributed, and again there will be a preponderance either of the one type of pebble or the other. The Main Reef in the mine indicated is the only one in which this feature of calcite pebbles is to be seen; the Main Reef Leader and South Reef showing only the usual silicious pebbles.

The placer school readily admit the possibility in the banket formation of chemical action subsequent to the deposition of the gold and pyrites and partial re-distribution of these metals, and in fact they attribute the flaky and filmy particles of crystalline gold, which are sometimes to be seen on the fracture faces of pebbles, entirely to this cause, but they do not admit the correctness of the theory of later infiltration of gold solutions—derived from some outside source—through the conglomerate beds after partial consolidation of the latter.

Under postulate (1) the contentious point between the placer and infiltration theories is plainly that of the preëxistence of gold

and pyrites deposited simultaneously with the pebbly mass, which the former theory asserts. A comparison of the claims of the two theories can only be made by referring the unknown factors to analogous conditions in deposits which are more recent and more easily understood.

In the placer gold deposits of the world we have an exact representation of the imaginary conditions which existed in the far off geological time when the conglomerate beds of the Rand were deposited. Physically the same conditions exactly reproduced, namely, water-worn pebbles, for the most part, granular quartzitic material, and as concomitants, gold and iron pyrites, the only difference being that the older deposit, through pressure exerted in the intervening geological epochs, has become an aggregated solid mass, and the latter, being of comparatively recent deposition, still lies more or less as a disintegrated mass in the condition in which it was originally laid.

The gold constituent in placers is almost universally held to have been deposited contemporaneously with the other materials making up the whole. Contrary opinions were advanced and based on laboratory tests by Daintree, Selwyn, Wilkinson, Skey and others, who claimed that gold could be made to grow *in situ* by precipitation from solution through the agency of organic matter. Despite, however, very scientific and elaborate arguments, these theories failed to satisfy some important conditions, namely: (1) The enclosure of gold in an arborescent form in specimens obtained from many alluvial washes, and also the fact that a large percentage of nuggets found near assumed sources of origin, retain fragments of attached quartz. (2) The practical fact that gold alluvial always occurs in the neighborhood of auriferous lodes, and the channels in the immediate neighborhood of said lodes are always richer in nuggets than those sections more distantly situated. (3) The fact that large masses of gold have been found in quartz veins all over the world.

The consensus of opinion remains therefore that the gold in recent placers was deposited contemporaneously with the other materials, and although there have undoubtedly been subsequent changes in these deposits, and in part, solution and re-precipitation

of the gold, it is believed that the views advanced by Daintree and others cited above have only been regarded by geological chemists at large as ingenious theories for a particular form of gold deposition, but as not applicable to the case of alluvial deposits in general. Since, then, we have a class of alluvial deposits, in nowise essentially differing from the ancient conglomerate beds, excepting as to aggregation of constituents, and since there appears to be at least a consensus of opinion favoring the contemporaneous deposition of the gold and pebbles in these younger washes, and since also the pebbles of these younger auriferous washes are invariably barren of gold—a feature which is one of the chief obstacles to the acceptance of the aqueous theory in connection with the Rand beds—we have at least some firm ground to tread upon in preferring the placer to the infiltration theory.[1]

History has a way of repeating itself in all the processes of nature, and it therefore appears to the writer reasonable and logical to explain ancient phenomena by the light of comparatively recent events, when the particular forces in each case are evidently the same in kind, if not in degree.

In postulate (2) of the infiltration theory it is assumed that the permeating gold solutions specially selected the Main Reef series of beds for enrichment to the prejudice of the other series of reefs which constitute the Witwatersrand series as a whole. It is not, I believe, claimed by the exponents of the infiltration theory that the Main Reef series of beds was permeated and charged with its gold contents prior to the permeation of the Bird Reef series or the Kimberley series, or if it is, then it calls for a theory of separate and convenient supplies of metalliferous solutions to suit the periods when these younger reefs were in a condition to be permeated.

Taking it then that the solutions were permeating the whole Witwatersrand area at one time we get some curious paradoxes. It is claimed for the infiltration theory generally that the porosity

[1] The writer is of course aware that alluvial cements have been crushed for the gold they contained, but in all cases within his knowledge the pebbles of these cements were barren; the cementing medium consisting generally of a mass of smaller pebbles, contained the water-worn gold particles in the interstitial spaces.

of the conglomerate beds accounts for the fact that grits and quartzites—which must also at that period have been porous—have not shared in the gold enrichment to any extent. But if it is a question of porosity—and this is insisted upon—then surely it is reasonable to suppose that the Kimberley Reef series, with its enormous width and large pebbles and younger age, would be far more porous than the Main Reef series. Also it is curious that the Main Reef—forming the underlying bed of the series to which it lends its name—which is the widest and most pebbly bed of the series, and therefore at that period the most porous, should be the least valuable in gold, whilst the other reefs of the series, which are generally much narrower and less easily permeated, are by far the most valuable.

The explanation of this phenomenon from the standpoint of the placer theorist can be illustrated in a few words. It has already been shown that geologically recent alluvial washes are in all essentials the counterpart of the ancient conglomerate beds which are represented in the Rand formation, and therefore we can again refer to these for explanation of those difficulties which I have shown the idea of porosity will not remove.

Any engineer who has worked alluvial wash to any extent has frequently experienced in the wash the occurrence of "false bottoms" in the working face, these being one or several, generally according to the thickness of material composing the wash. On these "false bottoms" the gold occurs concentrated to an extent only less in quantity and importance, to the concentration which is found on the actual "bottom," and these "false bottoms" denote in each instance a period of quiescence, during which time finer material was deposited in the wash, to be followed by another period of activity, when conditions similar in some degree to those which formed the heavy wash on the actual bottom obtained.

These "false bottoms" in the tertiary washes can be compared in the writer's view with the younger conglomerates of the Main Reef series, such as the Kimberley and Bird Reefs, whilst the Main Reef proper represents the correlative of the actual bottoms worked in the recent geological alluvials. Such a theory appeals

to the writer as a simple explanation based on reasoning from analogy, and as one not requiring the application of ingenious theories of selective chemical percolation to support it. He does not pretend that there are not difficulties which apparently refuse to be explained away in any theory which attempts an explanation of the gold impregnation of the Rand beds, but in his opinion the modest course for the scientist is to attempt to follow nature's finger-posts on the simplest lines, and therefrom to draw his tentative or final conclusions.

The enunciation of the placer theory of the origin of the gold in the Rand banket as expressed by the writer is in no sense submitted as indicating any other than his own individual views. An attempt has been made to illustrate some of the pros and cons in the case as they appear to the mind of a practical engineer interested professionally mainly in the economics of the gold deposits, and intended only as supplementary to the more professorial observations, investigations and conclusions of Professor Gregory.

G. A. DENNY.

THE DEFINITION OF MARL.

Sir: In reading the literature of fertilizing earths and of cement rocks, one is puzzled by the wide variety of rocks to which "marl" is applied, and I have been interested in searching for a correct definition of this loosely used term. In this respect modern text-books give little satisfaction, for their definitions of marl seldom agree.

Kemp says that marl is a calcareous clay of incoherent nature, but notes that the term abroad is applied to compact impure limestones. Scott, Jukes-Brown and Dana agree with this definition, and the latter mentions shell marl as ordinary marl in which shells are prominent. Pirsson, although defining marl as a friable mixture of lime or magnesium with clay, limits shell marl to a "white earthy deposit formed of fragments of shells of various organisms in inclosed basins of water." According to Chamberlain and Salisbury argillaceous impurities do not seem essential to marl, which they define as "an earth formed largely

of calcium carbonate, usually derived from the disintegration of shells; or the calcareous accretions of plants." G. P. Merrill's definition seems to include both Chamberlain and Salisbury's and that accepted by Kemp, Scott and Jukes-Brown. According to him "the name shell marl or merely marl is given to an illy defined often arenaceous deposit consisting essentially of shell material in a more or less fragmental condition, and usually intermixed with more or less clayey matter or siliceous sand and silt." LeConte uses the term for a calcareous shale—a gradation between limestone and shale. He makes no mention of incoherence.

Still another use of the term is that advanced by Geikie, who considers marl a fresh-water deposit, "a soft, white earthy or crumbling deposit formed in lakes or ponds by accumulation of shells and entomostraca."

According to the "Report of the Michigan Geological Survey," Vol. VIII., Part 3, this kind of material is extensively used in the cement industry of Michigan, and is locally termed marl. In this report both Lane and C. A. Davis remark that marl is not the correct name for such a deposit; nevertheless it does coincide with Geikie's "marl" and Pirsson's "shell marl."

The German "mergel" is used by both Zirkel and Rosenbush for mixtures of lime and clay which disintegrate on exposure to the air.

Thus in the few authorities quoted, we find marl applied by some exclusively to nearly pure lime earths of fresh water origin; by others exclusively to limey clays, origin of which is not mentioned and by others to both of these types indiscriminately, and to hard rocks, *i. e.,* calcareous shales. Shell marl is by some considered the equivalent of marl; by others applied to entirely different rocks. There is, moreover, the commercial usage according to which rocks (except possibly gypsum and the phosphate rock) valuable as fertilizers are marls.

The following notes, in the preparation of which I have been aided by suggestions from Professor H. Ries and by the library of Professor H. S. Williams, show that the early English and

American geologists had no generally accepted definition of marl.

In "A Natural History of the Earth," by John Woodward (London, 1723), is the vague statement in reference to the origin of stratified rocks: "At length all this metallic and mineral matter . . . subsided to the bottom; . . . as also the Sand, Cole, and Marle and other Matter whereof the Strata of Sandstone, Cole and Marle are for the most part composed." According to Conybeare and Phillips, "Outlines of Geology of London and Wales," Guettard in 1746 divided the earth into three zones—(1) schists, (2) marles, which include generally the secondary limestones, and (3) sands. Richard Kirvan, in "Geological Essays" (London, 1799), speaks of marlite, or indurated marl and semi-lapidified marl. The same conception of unconsolidated rock is found in Maclure's "Geology of the United States" (1817), in which marl is classed with alluvial rocks in distinction to the stratified. Mention is made of its limey character and its fertilizing properties. J. L. Comstock, in "Elements of Mineralogy" (Boston, 1821), described marl as a *mineral* which quickly falls to pieces on exposure to the air and which is clay and calcium carbonate. The idea of ready disintegration is not so emphasized by J. Maccullock's "Rocks" (London, 1821), in which marl is said to be more or less compact, *may* fall in pieces on exposure to the air, and passes into shale. Amos Eaton, in "Index to Geology of the United States" (1820), defines marl as a compact mass of carbonate of lime, clay and sand. His examples of shell marl in the "Textbook" (edition of 1830) are probably all of fresh water origin though this is not expressly stated. In some of the early treatises on geology, we find no attempt to define rocks on a basis of texture and composition, and in these cases marl is used for a wide variety of rock. Thus Blakewell, "Introduction to Geology" (1829), Conybeare and Philips (London, 1822) and De La Beche (1833) all refer to marl beds in the new red sandstone; to lower Cretacic marls, some of which are hard enough for building stones, and some of which at least are considered marine. On the other hand, Conybeare and Phillips also speak

of a rock that falls to pieces on drying as being a "marle of ordinary character." In 1844 C. A. Lee published in New York "Elements of Economic Geology," in which he defines marl as argillaceous carbonate of lime but notes that by custom it is any mineral with fertilizing properties. He also remarks that as the new red sandstone of the Connecticut valley contains considerable lime, it might be called a red marl.

About the middle of the century several text-books were published in which incoherence and clay-line composition were mentioned as essentials of a true marl. Among these were "Elements of Geology," by J. R. Loomis (Boston, 1852), Emmon's "Manual," (2d ed., 1860), Lyell's "Elements" (1865) and von Cotta's "Treatise on Lithology" (1862), translated by P. H. Lawrence in 1878. Wm. Humble in "Dictionary of Mineralogy and Geology" (1860) and Rutley in "Study of Rocks" (1879) apply marl to any mixture of clay and lime.

Among the older writers Edmund Hitchcock appears to have been the first to describe marl as a fresh water deposit. In his "Geology" (1853) we find: "Alluvial marl;—usually of fine powder consisting of carbonate of lime, clay and soluble and unsoluble grains. It is found usually beneath peat in limestone countries and sometimes at bottom of ponds. It contains numerous fresh water shells and has received the name of shell marl." Three varieties are recognized—calcareous, aluminous and siliceous. The last two contain practically no lime carbonate, the siliceous variety being infusorial earth.

From the above it seems that the general tendency has been to use marl for a calcareous clay, but many who have so defined it, in actual practice apply it to a wider range of rocks. Moreover, there is enough authority for other usages to show that marl has often been considered as something other than a friable lime-clay mixture.

According to the Century and Webster dictionaries marl comes from the low Latin *margila* which is the diminutive of the Latin *marga*. The original meaning of *marga* may be gathered from the following quotation from Pliny (*"De Re Natura"*):

"There is another method which has been invented both by the Gauls and Britons of enriching the earth by the agency of the earth itself and this kind (of earth) they call marl (*marga*)."

Several varieties of these fertilizing earths are described by Pliny, all of which are known by the same name. Tufaceous and white marls are found in the vicinity of springs, and are very fertile, but if "rough" may burn the soil. Red marl consists of stones mingled with thin sandy earth, and is broken up upon the land. Columbine marl is taken up in solid blocks that split into laminæ on exposure to the sun. Another variety of marl is white "chalk" used for cleaning silver.

With this origin of the term in view, it seems probable that marl has been applied in any one district to the particular kind of rock there used for fertilizers. The older geologists then formulated their definitions to cover the rock or rocks to which in their experiences the term marl had been applied.

In the writer's opinion no attempt should be made to use marl as a rock name with any of the limited meanings attached to it by the geologists quoted above. It should be employed in its original sense—as any rock that is valuable as a natural fertilizer (with the exception of the phosphate rocks and such well-defined minerals as gypsum which seem to be separated in general usage). This opinion is based, not only upon priority, but upon the following considerations: (1) Good authority exists for several widely different definitions, so that agreement to accept any one of them would probably be impossible. (2) Even if such agreement were reached the literature would still be filled with references to marls that would not fit the definition so agreed upon. (3) No matter what convention scientists may adopt, commercial usage will still apply marl to fertilizing earths. (4) When it is desired to convey a definite idea of the character of one of these rocks more specific term are available, as calcareous clay, argillaceous limestone, bog or fresh water lime, etc.

As far as the writer can see there is little authority or logical basis for applying marl and shell marl to distinct types of deposits.

ITHACA, N. Y. C. A. STEWART.

REVIEWS

The Geology of the Gold Fields of British Guiana. By J. B. HARRISON, Government Geologist, with historical, geographical and other chapters by Frank Fowler and C. Wilgress Anderson. 8vo, 320 pp., with 33 plates of views and 10 plates of microphotographs. London, Dulau and Co., 1908.

The present book summarizes the results of a geological investigation begun in 1897 and finished in 1905. For the most part these have appeared progressively in twelve earlier publications, most of which dealt with parts of the field now succinctly treated as a whole and, with other important contributions to the geology of the colony, are listed in the introductory chapter.

In chapter II. Mr. Fowler sketches briefly the history of gold mining in British Guiana from 1720 and supplies some tables from which it appears that the greatest production, 134,124 ounces, was in 1892, since when the output has declined rather steadily to 85,506 ounces in 1906. The total recorded production is given as 1,936,495 ounces. Five gold districts are officially recognized of which the Essequibo district, including the basin of the Potaro River, has in the past been the most important. We are not told which one at present has the greatest yield.

The general physiographic features and climate are described by Mr. Anderson in chapters III. and IV. The colony has an area of some 90,000 square miles, being about equal in extent to Great Britain. There is a low coastal belt, largely swampy but containing most of the sugar plantations and cultivated lands, which rises gradually inland for from 10 to 40 miles. It is succeeded by a slightly more elevated densely forested belt which, although narrow in the northwest, attains a width of about 100 miles at the Courantyne River, the eastern boundary of the colony. Behind this belt the country, still heavily wooded, rises toward the Brazilian frontier to a scarped and terraced grassy plateau, with a general altitude of about 3,500 feet. This is incised by deep river gorges and is surmounted by flat-topped sandstone and diabase peaks two of which, Roraima and Kukenaam, rise over 8,500 feet above sea.

The broad geological features, outlined in chapter V., are an alluvial coastal belt from 5 to 35 miles wide underlain by sands, clays of unknown thickness which are supposed to range in age from late Tertiary to recent. These deposits rest upon residual deposits or laterites derived

from the decomposition of underlying granites, gneisses and porphyritic intrusives. These rocks, considered as pre-Cambrian constitute the fundamental complex of the colony, occupy large areas of the interior, and underlie the gold districts. They are generally deeply decomposed to lateritic products and these in turn are covered by dense forest so that study of the crystalline rocks is limited to the exposures along the rivers during the dry season.

Resting upon this complex and forming the plateaus and mountains of the interior is a thick formation of coarse conglomerates, red and white sandstones and red shale of which the age is as yet unknown. This is intruded by dikes and great laccolithic sheets of diabase or gabbro.

Chapters VI. to VIII. are devoted to the petrography of the fundamental rocks which is illustrated by excellent photo-micrographs. A large number of complete and accurate chemical analyses accompany the description and the fresh rocks are assigned places in the quantitative system of classification. The failure to record explicitly the analyst responsible for so much good work is a serious omission. The only information vouchsafed in this respect is a statement in the introduction that the author has "received much assistance in making the numerous analyses and assays required from John Williams, Esquire, F.C.S., chief assistant analyst in the government laboratory." The reader who wishes to know who made a particular analysis is thus left in doubt by this rather ambiguous sentence.

The lithology of the clastic rocks is briefly described in chapter IX. and a good account of the intrusive diabase with numerous analyses constitutes chapter XI. This is followed by a description of the recent formations of which the residuary deposits are of most interest. These lateritic accumulations vary according to the rocks from which they have been derived. Aplite, granite, granitic gneiss and similar rocks give rise to white or cream-colored, more or less sandy clays. Diabase, diorite and related rocks on the other hand decompose to buff, red, brown or chocolate ferruginous and siliceous earths. Several analyses are given showing the chemical compositions of these products. The laterite deposits from the basic rocks are of economic importance since they form the matrix of much of the placer gold and carry auriferous quartz veins. They are red or ochreous sandy clays with layers of angular quartz fragments and of concretionary ironstone. Where rearranged by running water such material gives rise to beds of coarse ironstone gravels. The concretionary ironstone of the laterites is said to be for the most part auriferous, the gold contents ranging from mere traces to 0.8 ounce per ton.

Chapters XII. to XXI. are devoted to the descriptive geology of the

separate districts and are followed by a brief chapter purporting to deal with the structures of the auriferous districts but in reality made up of rather unsystematic jottings on various subjects. The truth of the matter is that very little is known of the structure of the country—a fact which is not at all surprising in view of the tropical character of the climate and vegetation.

Quartz veins and "mineralized masses" are accorded a short chapter of general description. The auriferous veins occur mainly in districts in which the general country rock is gneiss traversed by belts of epidiorite or of hornblendic or chloritic schist and cut by intrusions of diabase. The schists are regarded as the oldest rocks and are invariably more or less auriferous, the gold being partly in pyritic quartz veinlets and also "diffused through the rock." Whether the gold is original in these old metamorphosed basic igneous rocks or was introduced at the time of the granitic intrusions has not been determined. Many of the veins are enclosed in lateritic decomposition products of the original wall-rock and some of these are said to have been much enriched by secondary quartz and gold deposited during the process of rock decomposition. The Arzruni vein at Omai was worked in laterite but became poor and pinched out in the underlying aplite. The ore was rich and pockety, containing scheelite and some compound of tellurium.

The mineralized masses are chiefly aplitic or alaskitic rocks in which the gold is carried in countless minute veinlets of quartz which are regarded as being possibly injections of a residual auriferous residue from the original magma, although there is supposed to have been much subsequent enrichment during the intrusion and decomposition of the diabase. The reader is likely to conclude that the country is not one in which the problem of the original source of the gold can be attacked with much prospect of success.

The placer deposits are briefly described in chapter XXIV. and their origin is discussed in chapter XXV. Many have written on the placer gold of Guiana and the various opinions advanced are referred to. The author of the present work agrees with De Launay, Levat, Lungwitz and others that the placer gold is genetically related to the basic rather than to the acidic rocks. According to his view the gold originally present in the basic rocks is taken into solution during the deep decomposition of these into laterite and is concentrated by deposition upon particles of gold already present, or upon quartz, or in the concretionary ironstone. In order to determine the solubility of gold in the soil waters Mr. Harrison carefully assayed the ash of a tree trunk grown on laterite which covered the auriferous aplite at Omai. The wood was burnt separately from the back in a new muffle and furnace and blank assays were run at the same time. He found from 7 to 10 grains (that is, up to

about 0.02 ounce) of gold per ton of ash in his several trials. The laterite attains thicknesses of from 150 to 200 feet in some places and when water-soaked is said to flow down hillslopes and to allow the quartz fragments to subside to the bottom of the mass. The placer accumulations are in part accounted for by this process.

The work closes with a brief account of the soils of the mining districts, hints to miners and prospectors, an appendix giving the mining ordinance, and locality index.

One of the most interesting features of the book is records of the numerous assays made to determine the gold and silver contents of the various rocks studied. These show determinable quantities of these metals in practically all of the fresh rocks analyzed, the gold ranging up to 23 grains and the silver up to 85 grains per ton with of course larger quantities in those rocks that contain secondary quartz and pyrite. The assays appear to have been very carefully made, but unfortunately the record is not as complete and detailed as it should be for special work of this kind. In most cases, after a fresh rock has been described and analyzed the statement follows that assays on a sample of this rock yielded so much gold and so much silver. If it were definitely recorded that the analysis and assays were made on parts of the same sample the important question whether the rocks as they originally solidified from their magmas contain appreciable quantities of gold and silver would be more satisfactorily answered. As it is, there are hints here and there that the samples assayed contained pyrite and quartz veinlets or at least were not identical with the material used for chemical analysis. Thus the assays just fail of conviction on the point where converges the greatest interest in this particular line of investigation.

The work as a whole is well and carefully prepared and is admirably illustrated although the absence of any kind of a map is a defect. The book constitutes a valuable summary of the comparatively unfamiliar geological conditions that obtain in a tropical gold region.

F. L. RANSOME.

Economic Geology of the Georgetown Quadrangle (together with the Empire District), Colorado. By JOSIAH E. SPURR and GEORGE H. GARRY, with General Geology by SYDNEY H. BALL. Professional Paper U. S. Geological Survey, No. 63, 1908.

From the point of view of economic geology and mining, the Georgetown Quadrangle is, virtually, Clear Creek County, with the omission of the Empire District; and it seems a natural suggestion that the county or, better, the several mining districts which it embraces, taken collectively, would have been here, as usually throughout the west, the more appropriate and convenient unit of economic as distinguished from

systematic or areal (folio) publication. To the northward, in Gilpin and Boulder counties, are two other complete economic units. That this relation should hold very generally for the older mining districts is obvious from the fact that the counties were laid out or established from the mining districts as centers; and in Cripple Creek we have an instance of one of the newer mining districts for which a county was specially created.

Next to Gilpin County, with which it is closely continuous, Clear Creek County is the oldest mining district of Colorado and of the entire Rocky Mountain region, dating, as it does, from the "Pikes Peak" gold encitement of 1859. But although it is also one of the most important districts, its record (chiefly silver), approximately one hundred millions, while the record of Gilpin County (chiefly gold) exceeds that amount. Not until now has it received other than statistical attention from the U. S. Geological Survey, and the "Little Kingdom of Gilpin" still awaits its turn. Fortunately, however, these are long-lived districts, which half a century of active mining has not exhausted; and hence this long-delayed account of the Clear Creek County districts does not at all belong to the class of "obituary" reports; but it is likely to prove of practical value in the further development of the territory to which it relates.

A partial explanation, at least, of the apparent neglect of these older mining districts by the mining geologist lies in the fact that they antedate by a score of years the organization of the survey and were at its inception so fully developed and so flourishing as to feel less acutely than the younger districts, some of which are now well-nigh forgotten, the need of its aid. If further explanation were desired, it might profitably be sought in the essential geologic nature of the districts. For these are, in the main, highly complex plutonic and metamorphic areas, in which the guiding thread of stratigraphy, both sedimentary and volcanic, almost utterly fails; and it is no wonder that they did not attract the geologists of the last generation. But that the great modern advances in our knowledge of igneous and metamorphic rocks and processes and the genesis of ore deposits have at last made the investigation of these difficult fields profitable the present contribution bears ample testimony.

The geologic map of the quadrangle shows an ideal complex of metamorphic and igneous rocks, in which a basement of varied schists has been successively injected by no fewer than eight plutonic types and an elaborate series of porphyry dikes. The most distinctive feature of the map is the spotted or pseudo-porphyritic aspect due to the occurrence in several of the older formations of a multitude of minute areas—inclusions, intrusions and segregations—which are commonly dike-like in

form and surprisingly uniform in size and orientation. The plutonic rocks, belonging with the schists wholly to Pre-Cambrian time, include both massive and gneissic developments of various granites, of diorite, of monzonite and of still more basic types; and the granites especially present normal, pegmatitic, aplitic and porphyritic phases.

The porphyry dikes, of late Cretaceous or early Tertiary age, are almost as varied in composition as the plutonics. The territory traversed by the porphyry dikes and sheets forms a wide irregular belt or zone extending in a general northeast-southwest direction across the Front Range from the Great Plains near Boulder to the Arkansas Valley near Leadville, and traceable thence, in the same general direction but less continuously, across the successive ranges, to and through the San Juan district in the southwest corner of the state. One of the most striking and important generalizations of this work is the reference to this great diagonal zone of relatively recent igneous activity of nearly all of the principal precious metal mining districts of Colorado. The only important districts not fairly referable to this zone are Cripple Creek and Rosita; and these, it is well known, are vitally related to volcanic centers of still more recent activity. The great porphyry zone is primarily a zone of fractures and faults due to regional stress; and to this fissuring, which has continued down to the present day, may be attributed both the porphyry intrusions and the ore deposition.

The summary descriptions of all the mining districts of Colorado, with a view to showing the essential uniformity of the geologic conditions as affecting the ore deposits within and without the great porphyry zone, is a feature which the student cannot fail to appreciate. The chief result of this comparative study is the reference of the precious metal and lead deposits to two groups: (1) those whose formation followed injections of a monzonitic magma, including a large portion of the porphyry zone, and (2) those whose formation followed the outburst, in dikes and sheets of the porphyry zone and in isolated volcanic centers, of magmas having an alkaline or phonolitic tendency. Although both groups are of Tertiary age and probably overlap to some extent, it is concluded that the phonolitic magmas and accompanying ore deposits are, as a whole, younger than the monzonitic magmas and the ore deposits genetically related to them.

By the aid of the conclusions gained from this broad study, the special features of the Georgetown Quadrangle, which is but an arbitrary fraction of the porphyry zone, are investigated. It is pointed out that the ore-bearing veins, embracing, in distinct areas, auriferous pyritic veins and argentiferous galena-blende veins, show a general agreement in distribution and trend with the porphyry dikes; and according to the testimony of the Stanley Mine, which is assumed to be representative, the

vein formation closely followed the intrusion of the porphyries, so that a genetic relation between the two is regarded as unmistakable. Further, the two types of veins are believed to admit of definite and distinctive petrographic correlation, the argentiferous galena-blende veins occurring in association with dikes of alaskite porphyry, granite porphyry, quartz monzonite porphyry and dacite, and the auriferous pyritic veins with dikes of bostonite, alaskitic quartz monzonite, biotite latite and alkali-syenite.

Further investigation shows that the argentiferous veins, attending the monzonitic injections, and consisting of galena-blende and pyrite in a quartz gangue, are subject to alteration and concentration through the agency of cold descending surface waters. Paragenetic study indicates that the gangue minerals are derived from the wall rocks; that a large part of the material of the veins is immediately deposited by ordinary atmospheric waters; and that the original source of the metals is alone doubtful. The wall rocks of the veins have been altered to quartz, sericite, carbonates and kaolin; and this alteration, also, is attributed to the agency of descending waters. It is concluded that the original ores were predominant blende with galena and pyrite through a considerable vertical range, that the veins have been actively eroded, and that descending waters have rearranged and concentrated the ores, developing a bonanza zone a few hundred feet in depth, characterized by predominant galena and chalcopyrite. It is thus made to appear probable that magmatic waters have played no essential part in the formation of the argentiferous veins, except, possibly, as a source of the metals.

But the interpretation is radically different from the auriferous veins, consisting essentially of pyrite in a quartz gangue, although galena and blende are not wholly wanting. Not only are the primary ores the same for the two classes of veins, differing only in the relative proportions—predominant blende for the argentiferous veins and predominant pyrite for the auriferous veins; but the secondary or bonanza ores are the same; the gangue minerals are the same; the wall rocks, apart from the porphyry dikes, are the same; and the wall rocks, of whatever kind, are substantially similar in modes of alteration and in secondary minerals or alteration products, except that in a few instances adularia has been observed sparingly in the walls of the auriferous veins. But since the deposition of the auriferous veins is believed, on the evidence of the Stanley vein, to have followed closely the intrusion of certain dikes which contain fluorite, it is concluded that the mineralizing agents, at least as regards the ores, can have been nothing else than ascending hot waters, and that these waters, as well as the contained gases, were of magmatic origin.

The fact that in the auriferous districts the intrusion of a phonolitic

magma was followed by the deposition of a certain type of veins, whereas in the argentiferous districts the intrusion of a monzonitic magma resulted in the formation of another type differing from the first only in the proportions of the ore minerals, is thought to be explainable only by considering the metals to have been given off by the respective magmas, since the rocks which have been traversed by the ascending solutions are similar. This, too, in spite of the fact that for both types individual veins may be far removed from any known porphyry dikes; and regardless of the view that, after all, the auriferous veins, which now outcrop at relatively low levels, may be in general but the more deeply denuded portions of what at higher levels were argentiferous veins, a view which would accord well with the general vertical succession of ores in metalliferous veins, and that seems especially to find confirmation in the Idaho Springs district, where the veins are of distinctly intermediate type—both argentiferous and auriferous, and the ratio of gold to silver tends to vary inversely as the elevation. Apparently, the Centennial and other auriferous veins of the Georgetown district are not associated with phonolitic intrusions; and it is a significant fact that they outcrop in the very lowest part of the district. Although the ore values in the Centennial Mine, with which the reviewer is well acquainted, diminish with depth, the ratio of gold to silver increases with depth, and what is virtually the same vein becomes increasingly and markedly argentiferous upward in the Burrell and Big Chief Mines on Leavenworth Mountain and in the Griffith and Anglo-Saxon Mines on Griffith and Saxon Mountains.

In the opinion of the reviewer, the proposed classification of the veins is probably secondary rather than primary—based on alteration and not on origin; the correlation with particular types of prophyry intrusions is not well sustained; and the argument for the immediate derivation of even the metals from magmatic waters is inconclusive. Among the more significant facts may be noted: (1) The alteration of the wall rocks after the manner of meteoric waters, one of the chief products—quartz—being also the principal gangue mineral of the veins; (2) the remoteness of many veins from known porphyry intrusions; (3) the essential similarity of the veins in everything except the relative proportions of the metals, this sole disparity being, perhaps, a reasonable consequence of differential erosion; (4) the vein formation, which has evidently accompanied and followed the fissuring of the plutonic rocks and alteration of the walls, has been, in some instances, several times repeated, without, apparently, corresponding renewals of igneous activity; (5) Some of the porphyry dikes, even where closely following important veins, still retain intact original obsidian borders, thus affording conclusive proof of their geologic recency and indicating that they

have contributed relatively less to the formation of the veins than the granitic and gneissic rocks which both veins and dikes intersect. (6) Many of the veins have been proved to end downward in unmineralized fissures, and it is not improbable that all do so. Is it not, then, a fair presumption that the chief contribution of the dikes to the formation of the veins has been the localized heat required to stimulate the circulation and chemical activity of the ground water? And does not the burden of proof fairly rest upon those who maintain the contrary?

In this connection we may note the restoration of the well-matured Teritary topography, the wide, shallow valleys of which have been deeply trenched in the formation of the modern V-valleys and canyons. But it is not clear that the probable important relations of this ancient topography to the metalliferous veins has been duly appreciated, and the suggestion is ventured that we have in this old land surface, and especially in the base-levelled floors of the Tertiary valleys a datum from which secondary enrichment may be measured, the development of the modern valleys having been more rapid than the downward migration of the bonanza zone, thus constituting a process of underhand stoping which has cost the miner by far the largest part of his treasure, and which, at the same time, has determined or, at the least, emphasized the distinction of the argentiferous and auriferous veins.

W. O. CROSBY.

SCIENTIFIC NOTES AND NEWS[1]

THE STATE OF TENNESSEE has at last fallen into line in inaugurating a geological survey. The legislature which has recently adjourned enacted a law establishing a state geological survey and appropriating therefor for each of the years 1910 and 1911 the amount of fifteen thousand dollars. The bill, which was prepared by Dr. C. H. Gordon, professor of geology and mineralogy in the University of Tennessee, provides for a commission consisting of the Governor, who is ex-officio chairman, the State Secretary of Agriculture, the State Inspector of Mines, and the heads of each of the three leading educational institutions of the state—the University of Tennessee, Vanderbilt University and the University of the South (Sewanee). The commission will meet within thirty days to appoint a state geologist and to perfect plans for the inauguration of the work of the survey with the beginning of the year 1910.

Tennessee is a very attractive field to the geologist and in the range and wealth of its mineral resources is exceeded by few of the eastern states. It stands eighteenth in mineral production and of the southern states Alabama alone exceeds it. In the production of lime phosphate it is exceeded by Florida only and in that of barytes by Missouri. It stands sixth in the production of copper, seventh in coke, eighth in pig iron, and twelfth in coal.

PROF. T. A. JAGGAR, of Massachusetts Institute of Technology, is spending the summer in Japan studying earthquake phenomena, and Prof. R. A. Daly, of the same institution, in the Hawaiian Islands for the same purpose.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

HORACE V. WINCHELL returned on June 25 from a three month's trip to Europe.

THE STATE OF WASHINGTON has recently made an appropriation for a geological survey and appointed Prof. Henry Landes, state geologist. The Federal Survey will coöperate with the state in topographic mapping and a study of the water resources and coal lands.

T. A. RICKARD, of San Francisco, has gone to London to engage in journalistic work in connection with mining.

A. C. SPENCER, Sidney Paige and F. H. Kay, of the U. S. Geological Survey, began work the middle of May on the areal and economic geology of two quadrangles in the central mineral district of Texas.

THE POPULAR SUBSCRIPTION for a monument to be placed over the grave of Major J. W. Powell in Arlington National Cemetery amounted on May 25 to $765 in cash, with pledges of about $300 more. This sum is from single subscriptions ranging from 50 cents to $100, by far the larger number of subscriptions being for $1 or $5. Col. H. C. Rizer, U. S. Geological Survey, Washington, D. C., is treasurer of the fund and will be pleased to hear from any of the friends of Major Powell who desire to have a share in erecting a monument to him.

AT THE REQUEST of the Canadian Geological Survey for the loan of a topographer, the United States Geological Survey has granted R. H. Chapman leave of absence for one year and he is at present engaged in topographic work for the Canadian government.

W. C. MENDENHALL and M. R. Campbell of the U. S. Geological Survey and Prof. H. E. Gregory, of the Geological Department of Yale, went to northeast Arizona the first of May to investigate water supply questions and the need of coal land classification.

LAWRENCE LAFORGE continues his work on the areal geology of the Boston region this summer and is at present located at Cambridge.

MISS JULIA MCCORD, who has been assistant librarian of the United States Geological Survey for a number of years, has been made librarian as a result of passing a difficult civil service examination. As this is the largest geological library in the country it is an important position which Miss McCord holds, and her many friends among the geologists of the entire country will be pleased to learn of her advancement.

THE ARKANSAS GEOLOGICAL SURVEY has been continued with an appropriation of $5,000 a year for two years. Coöperative work with the Federal Survey will be done, especially in the investigation of water powers and structural material. The state will also make a study of mining methods and waste in the coal fields with a view of conservation of its resources.

DRS. F. W. CLARK AND DAVID T. DAY, of the Geological Survey, are attending the Congress of Industrial Chemists in London.

THE NATIONAL GEOGRAPHIC SOCIETY has appropriated $5,000 for a continuation of studies of Alaskan glaciers by Profs. R. S. Tarr and Lawrence Martin. They will begin their work this summer at Yakutat Bay, and going west spend some time in Prince William Sound and possibly go inland to the Copper River country.

W. T. GRISWOLD, who was with the United States Geological Survey for twenty years, most of that time in the topographic branch, but later in the geologic branch investigating the accumulation of gas and oil, has for the past two years been engaged in private work in Pennsylvania and Ohio. After his resignation from the survey two years ago he was for a time with Guffey and Galey, of Pittsburg, but has now opened an office in Marietta, Ohio, and joined with him a corps of engineers for the purpose of applying the methods and principles developed in the service of the Geological Survey to the location of oil and gas territory. Mr. Griswold is prepared to make detailed topographic and geologic maps for mining and engineering purposes, and now has a force of fifteen to twenty men in the field. The

accuracy and value of the methods and principles used by the Geological Survey in this kind of work are reflected in Mr. Griswold's success in the development of oil and gas pools in his chosen territory.

PRESIDENT CHARLES R. VAN HISE, of the University of Wisconsin has announced that he will give a course of instruction next year in the geological department on the conservation of natural resources. To those who know Dr. Van Hise's charm as a lecturer this is good news, for his administrative duties have until now prevented his resuming teaching.

E. C. HARDER AND J. L. RICH, of the Geological Survey, have gone to California to spend the summer in a study of the iron ores in the southern part of the state.

HOYT S. GALE AND R. W. RICHARDS, of the Geological Survey, have been detailed to examine and classify phosphate lands in Idaho during the coming summer.

THE CLASSIFICATION OF COAL LANDS in the western states will be continued this year by the U. S. Geological Survey with twelve parties in the field. Following is a list of the coal fields to be examined, the chiefs of parties and the first assistants: Crested Butte field, Colorado, W. T. Lee and E. L. DeGolyer; Yampa field, Colorado, J. A. Davis and Frank R. Clark; Upper Powder River, Wyo., C. H. Wegemann and R. W. Howell; Lower Powder River, Wyo., and Bull Mts., Montana, C. T. Lupton and Henry Hinds; Wind River basin, Wyo., E. C. Woodruff and D. E. Winchester; Glenwood Spring, Colo., A. L. Beekly and E. F. Schramm; Assinniboine field, Montana, L. J. Pepperberg and J. H. Bridges; Livingston field, Montana, W. R. Calvert and V. H. Barnett; Coos Bay field, Oregon, J. S. Diller and Max A. Pishel; Black Hills field, Wyoming, R. W. Stone; Durango field, Colorado, J. H. Gardner; Washington coal fields, E. E. Smith.

THE AREAL GEOLOGY of the Ignacio Quadrangle, Colorado, will be mapped this summer by Whitman Cross and J. H. Gardner, of the Geological Survey, for folio publication. The region

in the vicinity of Durango, which is the principal town in the quadrangle, is the type section for the stratigraphy of a wide area.

FOR A NUMBER OF YEARS the United States Geological Survey has coöperated with state surveys in topographic work on the basis of equal appropriations. For every thousand dollars put up by the state the Federal Survey expended an equal amount. This year however, the amount of coöperative work asked for by the state surveys exceeds the amount which the government has to spend, in spite of the additional $50,000 given to topographic surveys this year.

THE U. S. GEOLOGICAL SURVEY has just opened at Denver a permanent branch office to facilitate the transaction of its western work, thus providing a base of supplies for the large corps of engineers who are kept in the field many months each year, making geologic studies of mineral deposits, conducting detailed topographic surveys for the base maps of the geologic atlas of the United States, mapping the great national forests, investigating surface and underground waters, and collecting statistics of mineral production. The establishment of such a branch office is not only intended to serve the convenience of the survey corps, but it is designed also to meet the great need of the western public for a source of information less remote than Washington. A supply of copies of the publications available for free distribution will be kept on hand, as well as a complete file of the topographic maps, geologic folios, and other publications of the survey subject to sale. All of these publications will be open to inspection by persons desiring information concerning the subjects treated. Prospective purchasers of maps and folios will be referred to the nearest sales agent, and the free publications will be distributed in Denver to those making application. In short, the Denver office is intended to serve the public in all matters that lie legitimately within the province of the United States Geological Survey. The office is located in the Commonwealth Building and was opened on the first of April. R. C. Miles, special disbursing agent, is at present in

charge, and will answer all inquiries, distribute documents, and maintain a visitors' register.

DR. HEINRICH RIES, professor of economic geology at Cornell University, has been commissioned by the Canadian government to make a survey of the clay deposits of Canada.

THE BILL TO ESTABLISH a state geological survey in Tennessee has passed both houses of the legislature by a large majority. The bill provides for a commission composed of the governor, secretary of agriculture, state inspector of mines and the heads of the three leading educational institutions of the state, the University of Tennessee, Vanderbilt University and the University of the South (Sewanee). The act carries an appropriation of fifteen thousand dollars for each of the years 1910 and 1911. In view of the unusual expenditures for 1909 the appropriation was not made available until 1910.

A NEW INDEX MAP OF ALASKA, showing areas covered by topographic surveys, has been issued by the U. S. Geological Survey. On the back of this map is printed a list of the survey's publications on Alaska, arranged geographically. These publications comprise 28 maps and 119 reports. The work of the Geological Survey in Alaska, begun in 1898, has been indispensable to the development of the mineral resources of the territory. The value of the mineral output of Alaska to date is approximately $148,000,000, including the values of gold, silver, copper, coal, tin, marble and other minerals. The cost of the survey's explorations in the territory has been less than three tenths of 1 per cent. of the total value of the mineral productions. Since 1898 areas in Alaska amounting to 121,252 square miles have been topographicaly surveyed on a scale of four miles to the inch and 2,732 square miles on a scale of one mile to the inch. These surveys cover, respectively, 20.85 and 0.47 per cent. of the total area of Alaska, which is 586,400 square miles. During the same period geologic reconnaissance maps have been made of 99,350 square miles and detailed geologic maps of 2,304 square miles. In addition to this work, practically every mining district in Alaska has been examined.

and some have been mapped in great detail. The water resources of some of the important placer districts have also been studied and the results published.

FROM A CIRCULAR OF INFORMATION recently out by the U. S. Geological Survey the following item will be of interest as stating the policy of the government concerning coal lands. The national policy of promoting the most advantageous disposal of the public lands is under the direction of Secretary Ballinger and by his instructions the director of the U. S. Geological Survey is transmitting to the Commissioner of the General Land Office land classifications based upon the reports of findings of the field geologists. To the fullest extent possible under the law the effort is to secure the wisest utilization of the resources of the public domain.

Recently enacted legislation gives to the agricultural entryman whose entry was made prior to the passage of the act the privilege of electing to take the surface rights, while the coal rights are reserved for future and separate disposition. The chief of the Denver field division of the General Land Office reports that from information received in his office 90 per cent. of the Colorado entrymen in areas supposed to contain coal will elect to take title to the surface, reserving to the United States the coal rights. This alone indicates the value and wisdom of this legislation which is the first important amendment of the coal land act along the lines urged by Mr. Ballinger in 1907, when Commissioner of the General Land Office.

If the entryman, on the other hand, chooses to contest, then the issue becomes one of relative worth between agricultural and coal values. In a report to Secretary Ballinger the director of the survey stated that in the case of the North Dakota lands, to which this act was supposed to be specially applicable, while all western North Dakota, a part of which had been withdrawn as coal lands, is believed by the geologists of the survey to be actually underlain by workable deposits of lignite, yet in all but fifty-four townships this area is conceded to be at present more

valuable for agricultural purposes than for its deposits of low-grade coal.

The regulations for the classification and valuation of the government coal lands as revised in April provide for a somewhat more discriminating separation of the coal and non-coal lands and for the fixing of more adequate valuations upon lands underlain by the higher grades of coal. These changes were determined upon by the Secretary of the Interior from the consideration of present conditions in coal mining in the western states, where thinner and deeper beds are being mined than was formerly the case, and of current practice in the matter of coal royalties collected both by the states and by private land owners. Two of the regulations indicate the spirit of these administrative measures for safeguarding the disposal of the nation's remaining coal lands. The price of coal land containing the lowest-grade bituminous coals or lignites is fixed at the minimum provided by law, the intention being to thus encourage, so far as the law permits, the immediate utilization of these low-grade fuels. Another rule states that in all valuations of coal beds any special condition enhancing the value of the land for coal-mining purposes shall be taken into consideration.

The revised scheme used in the valuation of the coal lands differs from that formerly in force in two general respects. The basis is now specifically that of coal tonnage and the land prices thus determined for the better grades of coal, anthracite and coking bituminous, are somewhat higher, the maximum being raised from $100 to $300 per acre, and indeed this maximum does not hold in "districts which contain large coal mines where the character and extent of the coal deposits are well known to the purchaser."

The plan of valuing the public coal lands by accurate determination of coal quality and tonnage is the most equitable possible, and while adequate returns are secured to the government the land prices thus fixed rarely amount to one fourth of the royalties prevailing in the same districts among private interests.

The present scheme of valuation is as follows: Anthracite

and coking bituminous coals are valued at 2 to 3 cents a ton. High-grade non-coking bituminous coals are valued at 1 cent to 2 cents a ton. High-grade subbituminous and low-grade bituminous coals are valued at ½ cent to 1 cent a ton. Low-grade subbituminous coals and lignites are valued at the minimum price fixed by law of $10 and $20 an acre. The tonnage is very conservatively estimated and actual recovery ought always to exceed the tonnage upon which the valuation is based.

A few instances are cited as showing the comparative working out of valuations under the different land policies. In one township near Rock Springs, Wyoming, the valuation of which has just been completed by the Geological Survey, the coal land values aggregate $2,800,000 on the basis of 1 cent a ton. The amount for which the government would have sold these lands on the basis of the minimum price allowed by law, under the interpretation which held prior to 1906, is $460,000, while under the valuation plan of last year, the amount would have been a little less than $1,000,000.

In a Montana township, near the town of Roundup, on the new line of the Milwaukee, the original amount which the government would have received under the $20 minimum rate was $112,000; under the regulations of last year, $141,000; and under the present valuation scheme adopted April 21, by this administration, $370,000, some of the coal being now valued at $65 an acre where $20 and $25 respectively would have been the former rates.

Near the great Castlegate coal field in Utah, the survey is now valuing some of the government land containing thick beds of coking coal. In this field thousands of acres would run over the maximum of $300 an acre, as opposed to the $20 minimum price and $75 under the former valuation scheme. Dozens of other equally striking instances of comparative valuations might be cited.

The conservatism of even the present valuation plan is clearly shown from an examination of the record in several cases where land was fraudulently entered by certain companies and in which

suit for recovery of land and damages was instituted by the government. In one instance of this kind a coal company secured a tract of land through fradulent entries—paying $20 an acre, however—and instituted mining operations. The company has settled by paying the government 8 cents a ton royalty for all the coal mined and would have gladly accepted the privilege of being alowed to continue the mining at this rate. This, however, was not possible under the law. In this case the government received the original $20 an acre, as well as $31,000 in royalty for the partial working of the coal on the 74 acres involved, and has also got back the land. Had the company been permitted to mine out the coal, including that left as pillars, the return to the government would have been $1,320 an acre. Under the present scheme of valuation this land would have been sold at $340 an acre.

Not only are the prices determined on the basis of the present plan believed to be not excessive, but a higher valuation would have been very properly approved by Secretary Ballinger were it not for the fact that the coal-land law limits the coal land that may be acquired to an acreage below what a mining company needs for economical operation. It is evident that a purchaser could well afford to pay a larger price per acre did the law permit the purchase of the larger tract.

It will be seen that the present coal-land policy provides for the saving to the government and the people of enormous sums of money and prevents the monopolization by private interest of the western coal fields. The most advanced, scientific, and effective methods of classifying and valuing the nation's remaining coal lands, which still constitute about 80,000,000 acres, have been adopted, and in brief the intent of the policy developed by Secretary Garfield and now further advanced by Secretary Ballinger is to promote development and economical utilization and at the same time to secure adequate returns from these valuable public lands.

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